FMU Rep. No. IV-18.2
(OCTOBER 1968)

INDIA METEOROLOGICAL DEPARTMENT

FORECASTING MANUAL

PART IV

COMPREHENSIVE ARTICLES ON SELECTED TOPICS

18.2. MONSOONS OF INDIA:

SYNOPTIC FEATURES ASSOCIATED WITH ONSET OF SOUTHWEST MONSOON OVER KERALA

BY

R. ANANTHAKRISHNAN, V. SRINIVASAN, A.R. RAMAKRISHNAN and R. JAMBUNATHAN

ISSUED BY

THE DEPUTY DIRECTOR GENERAL OF OBSERVATORIES (FORECASTING)

POONA-5

[illegible]
(October 1968)

FORECASTING MANUAL

Part IV. Comprehensive Articles on Selected Topics

18.2 Monsoons of India

Synoptic features associated with onset of Southwest Monsoon over Kerala.

by

N. Ananthakrishnan, V. Srinivasan, A.R. Ramakrishnan and R. Jambunathan

1. Introduction.

In FMU. Report No. IV - 18.1 the importance of rainfall distribution along the coastal stations of Kerala and the Arabian Sea Islands for declaring the onset of the southwest monsoon has been emphasised. In the present report it is proposed to discuss the synoptic features (surface and upper air) over India and neighbourhood at the time of onset of the monsoon. Forecasters and research workers over the past seven or eight decades have noted and described in the departmental weather reports and scientific papers various aspects associated with the onset and establishment of the southwest monsoon over India. Before routine upper air observations became available the synoptic features on which attention was focussed were confined largely to the sea level charts supplemented by inferences drawn from cloud movements. The data from pilot balloon, radiosonde and rawin observations which have been steadily increasing since 1930 have made possible to extend the studies to higher levels. Since 1960 the weather satellites have been furnishing valuable data relating to cloud systems associated with the monsoon. All these have provided a three dimensional picture of the southwest monsoon.

2. Survey of Earlier Work

2.1 In the "Handbook of Cyclonic Storms in the Bay of Bengal for the [illegible] slightly revised edition published by IMD in 1944), Eliot has described the conditions leading to the onset and establishment of the southwest monsoon over India as follows:—

(i) "In the latter part of May and the beginning of June, southeast winds prevail in the Indian Ocean from Lat 30°S to the equator and west/southwesterly and winds from Lat 2° or 3°N to the head of the Bay of Bengal. The intermediate belt over and to the north of the equator is an area of light, unsteady winds with showery weather, thunder squalls, etc. There is hence a clear and marked separation between the two horizontal systems in the Indian Ocean and the Bay of Bengal. A comparatively sudden change usually occurs early in June, in virtue of which the intermediate belt of light variable winds disappears and a continuous horizontal air movement is established over the whole area from Lat 30°S to India and Burma. There is little change in the direction of the mean winds, except in and near the equator, where they veer rapidly from southeast through south to southwest and westsouthwest in passing through the equatorial belt. This change is accompanied by a large rush of damp air from the Indian Ocean across the equatorial belt into the Bay of Bengal and the Arabian Sea. One important effect of this is to change the lower air current in the Bay from one of shallow depth (perhaps 5,000 feet) to one of great depth, probably exceeding 15,000 feet. As might be expected, the vast inrush of moist air from the south of the Bay gives rise to a very large amount of irregular disturbance, more especially to much rain and frequent squalls. This action frequently tends to localize and intensify over the centre of the Bay, with the result that the advance of this moist inrush very often gives rise to a cyclonic storm of considerable to great intensity in each sea area".

(ii) "An examination of the data furnished for many years by vessels entering the ports of Bombay and Calcutta shows most clearly the nature of the change. Previous to the change the air movements in the Indian Ocean and the Indian Seas are distinct and separate. In the equatorial belt between these two areas light, variable winds and calms with much cloud and rain obtain previous to the change. These winds and weather in the equatorial belt are due to the continuation of the southeast trade winds as a vertical or ascensional movement and not as a horizontal movement over that area. In consequence of a gradual change of pressure conditions over the whole area, the nature of which would require more explanation than can be given here, the horizontal air movement of the southeast trades

bursts across the equatorial belt (over which the antisolstitial movement ceases almost entirely ceases) and is continued northward over the Indian Seas. The air movement of the southeast trades is much vaster and deeper than that of the previous local air movement in the Indian Seas. This rapid advance of the air movement of the southeast trades into the Indian Seas hence changes very considerably the air movement in the Bay of Bengal. It replaces the local unsteady and shallow air movement by a general large and deep current, which brings up moisture from a sea area of upwards of ten times the extent of the Indian Seas. There is hence a very large and radical change in the character of the winds and weather in the Bay in the month of June. It is then that what should be called the southwest monsoon proper is really initiated and from which it dates."

2.2 In a lecture on "The Southwest Monsoon" delivered before the Royal Meteorological Society Simpson (1921) has stated that "The monsoon is not the simple result of a single physical condition. It is produced by a combination of circumstances, involving consideration of temperature, pressure, humidity, geographical relationships between land and sea, the rotation of the earth, and lastly, but probably the most important, the distribution of mountain ranges." The main causes of the monsoon in India according to him are-

"(a) The primary cause of the monsoon is the difference of temperature over land and sea.

(b) The relatively high temperature over the land in the northern hemisphere during the summer tends to lower the pressure there.

(c) As the pressure falls over the land air motion results. The air motion is acted on by the rotation of the earth, it also modifies the original temperature distribution, which again modifies the original pressure. The result of all these interactions, each of which affects the others, is a closed low pressure system over the whole of Asia and North Africa, with the lowest pressure in the northwest of India. The pressure distribution in this final system bears no close relationship to the actual temperature in its different parts.

(d) The air over the north of Indian Ocean (including the Arabian Sea and the Bay of Bengal) takes part in the general motion set up by this huge pressure system. As this ocean is situated in the southern quadrant of the system the air motion over it is from the southwest.

sure rises over the ocean in the southern hemisphere. The resulting air motion affected by the earth's rotation and the distribution of land in the southern hemisphere, modifies the pressure system in the south of the Indian Ocean.

(f) The air in the south of the Indian Ocean moves, under the influence of this pressure distribution and of the rotation of the earth, towards the northwest as far as the equator.

(g) At the equator the air from the south is caught up in the circulation around the low pressure system in the northern hemisphere, and moves towards the northeast.

(h) The southwest air motion over the north of the Indian Ocean is therefore a continuation of the southeast air motion over the south of the Ocean.

(i) In consequence the air which reaches the Indian area has travelled for 4000 miles over the ocean, and is therefore highly charged with aqueous vapour.

(j) The southwest air current over the north of the Indian Ocean, which is impelled forward by forces extending over the whole region of its motion, is directed towards the high mountains of India, which are so arranged as to form a barrier to the north and to the east. The air is caught in a kind of trap, out of which there is no escape except by rising.

(k) The consequence of the forced ascensional motion is heavy rain over the Indian area.

(l) The actual distribution of the rain is determined by the ranges of mountains in and around India. The sides of mountains which directly meet the currents have heavy rainfall, while the regions behind the mountains are relatively dry.

(m) The dry region in the northwest of India is due to the arrangement of the neighbouring mountains, which prevents a large inflow of moist air into this region. A dry upper wind and the high temperature also help in preventing precipitation."

2.3 In the Introduction to "Weather in the Indian Ocean" published by the British Meteorological Office (1942) the conditions leading to the onset and establishment of the southwest monsoon over India have been described as follows:

"April and May: Pressure is becoming low in the Indian region, and the northern Indian Ocean is now subject to intermittent surges of southwest monsoon

air, which are derived from incursions of the southeast trades northwards across the equator, more especially into the southwestern Arabian Sea and the southern Bay of Bengal, where there are also occasional periods of relative calm. The northeast monsoon is correspondingly in retreat, but tends to remain in occupation of the eastern Arabian Sea and thus bars the southwest monsoon from the west coast of India. Even when the southwest wind does begin to reach across the Arabian Sea its first advent brings little rain to western India because of the lack of depth of the air stream and its trajectory over eastern Africa. During May air from the southern hemisphere eventually penetrates in the lower levels as far as northern India and southern Arabia, where the seasonal monsoonal low pressure area is now situated, and the ITF is thus carried to those regions (and across the south China sea) but it may not be active over the whole of its length. From the point of view of rainfall, however, which appears to require the southerly air stream to exceed about 2 km in thickness (at least for northeastern India) the southwest monsoon will only be commencing its advance up the Indian Peninsula, although to the east it will usually have reached the central Bay of Bengal and Burma. On the west coast of India the onset or burst of the rainbearing monsoon winds (usually towards the end of May) is preceded by large clouds advancing daily over the mountains about noon in a westerly direction against the surface wind, being carried by the remnants of the northeast monsoon circulation persisting aloft."

"June: The southwest monsoon air is derived from the southeast trades of the southern hemisphere where the subtropical anticyclones have increased in intensity and are now more north, their centres moving eastwards at about latitude 30°S. Pressure over southern Africa and Australia has become high, while the seasonal monsoonal low is now present to the northwest of India. The resulting equatorial monsoon air stream has a depth of about 6 km over a considerable part of India and the adjoining seas, the high humidity extending to the upper levels."

2.4 Roy (1946) applied the air mass method of analysing synoptic weather charts and described the conditions associated with the onset of the southwest monsoon as an advance of the equatorial maritime air from the south to north. According to him, "the field of the Equatorial Maritime (Em) air is restricted to below Lat 5°N in April, extends to the south and east Bay of Bengal and Tenasserim by mid-May, and advances into the southeast Arabian Sea, extreme south of the Peninsula, the north Bay, [illegible] the end of the month.....The advance of the cold maritime air over warmer land or sea surface creates instability in the lower layers and this together with the marked latent instability which exists in the atmosphere as a result of the lower moist air being overrun by dry continental air with large lapse rate, leads to the development mainly of Cu and Cb clouds, showers, thunder-storms and squalls which are more frequent over land in the afternoons. A marked fall of day temperature, especially at high level stations with a little or no change in night temperature, passing low clouds during day and showery weather with thunderstorms in the afternoon and evening indicate the first advance inland of this air mass."

2.5 Malurkar in his "Notes on Analysis of Weather of India and neighbourhood" (1950) has concluded that monsoon 'pulses' or low pressure areas carrying fresh monsoon or maritime air travelling south of the equator in a westerly or westnorthwesterly direction got deflected northward across the equator, if at that epoch a high pressure ridge interposes across its westward path and if the pressure south of the pulse also increases. He has stated that "The advent of southwest monsoon depends on the passage at discrete intervals of the fresh monsoon air across the equator. In some years, the first pulse may cross into the north Indian Ocean earlier than usual. The successive passages may also be maintained. Then the country has an early monsoon. It is a matter of considerable interest to detect this synoptically. The fresh monsoon air can be made easily unstable and would show itself by large number of thunderstorms in the Peninsula.....The formation and travel of depression in the Bay of Bengal or Arabian Sea would indicate the earlier incursion of equatorial maritime (Em) air north of the equator.....If westward moving depressions form earlier in the Bay of Bengal or the Arabian Sea, Em must have crossed the equator earlier than usual. If the thunderstorm activity in the Peninsula is not below normal thereafter, it shows that the incursion of Em has been maintained. It is possible that no depressions form but only there is great activity of Peninsular thunderstorms, from an earlier date than usual and is maintained thereafter. In both the cases an early advent of monsoon can be expected."

2.6 From the analysis of the 500 mb upper air charts for May and June 1946, Rao (1949) found that the burst of the southwest monsoon was associated with

certain large scale circulation changes over the northern hemisphere. His main findings are:-

(i) "(a) The burst of the monsoon occurs as a mean low-latitude upper-air trough is displaced rapidly from one steady position near 90°E to another relatively steady position near 80°E.

(b) One factor that sets the low-latitude trough in motion is the northward displacement of a low-latitude westerly jet. As this jet begins to circle the Himalayas to their north rather than to their south, an orographically imposed phase shift of low-latitude mean trough and ridge positions necessarily follows.

(c) The northward displacement of the low-latitude jet correlates in time with a general rearrangement of the northern hemisphere long-wave pattern that results in a replacement of a mean ridge by a mean trough over central Siberia. A Polar trough then extends all the way from Siberia to the Tropics".

(ii) "The combination of these two factors — collapse of the southern jet and the rapid westward displacement of the low-latitude trough — when superposed on the pressure gradient resulting from the large scale differential heating, results in the observed violent advance northward of the equatorial convergence zone. Thus a temporary northward displacement of the westerlies would produce only a temporary advance of the monsoon followed by a retreat if the westerlies returned to their original latitude".

2.7 Riehl (1954) quoting the analysis of Yin, identified the forward edge of the monsoon with the equatorial shear line which could be located with greatest accuracy at 700 mb.

2.8 Yeh, Dao and Li (1959) studied the change of circulation from winter to summer utilising the data over Asia for five years and have reproduced a series of charts for 1956. They found that in the last five days of May 1956 the southern branch of strong upper westerlies suddenly disappeared and easterlies advanced to the southern rim of the Himalayas. At the same time the southwest monsoon rushed northward. According to them the coincidence of the time of disappearance or retreat of the southern jet and that of the outburst of the southwest monsoon is not peculiar to 1956 and 1946 (studied by Yin) but is common to all the five years of their study. Hence they concluded that "with the onset of the normal upper air circulation the onset of the west monsoon occurs over India". Similar results have also been reported by Staff Members of Institute of Geophysics and Meteorology, Academica Sinica (1958), Murakami (1958) and Dao Shih Yen and Chen Hung Shun (1957).

2.9 Ramaswamy (1965) studied the upper air conditions over Asia during years of early and late onsets of the monsoon. He has pointed out that the westerly jet stream plays an important role in advancing or delaying the onset of the monsoon over India by its meandering to the north and the south of the Himalayas. He prepared diagrams representing the mean conditions, at the 200 mb level associated with unusually early onset of the monsoon in 1956 and unusually late onset in 1957 and found striking differences. The major differences in the patterns were summarised by him as follows:-

(i) Early onset of monsoon.

(a) There is a well-marked anticyclone extending from Northeast Africa to West Pakistan and Northwest India with a closed anticyclonic cell over south-west Pakistan and the adjoining parts of Iran.

(b) The westerly jet lies to the north of the Himalayas near Lat 40°N with the anticyclone referred to in (a) above, to its south.

(c) A long wave-trough runs from NNE to SSW over U.S.S.R. and from there to over the Black Sea and Adriatic Sea. Another similar long-wave trough runs with its axis roughly between Long 110° and 120°E.

(ii) Late onset of monsoon.

(a) The anticyclone over northeast Africa extends only upto Saudi Arabia. The closed anticyclonic cell seen over Southwest Pakistan and the adjoining areas seen in the case of early onset is completely absent.

(b) A trough is seen over northeast India with its axis near 80°E.

(c) The westerly stream is split, one branch flowing to the north of the Himalayas and the other to the south of the mountain range as we normally see in the pre-monsoon period. Observations at higher levels also show that, in the southern branch, wind speeds reached jet intensity. During the period 14-18 June, Peshawar winds were WSW/NNW 60 to 75 knots while New Delhi winds were N/NW 35/45 knots below 12.0 kms. In contrast to this, New Delhi winds were N/NE 5/12 knots during the same period at the same levels in June 1956.

From this he concludes that the mean conditions in the year of late onset

represents a pre-monsoon type of flow-pattern in the middle troposphere and by inference, also in the upper troposphere.

2.10 Flohn (1960) put forward the hypothesis that the seasonal warming of the elevated Tibetan Plateau serves as a mid-troposphere heat surface leading to to the reversal of the normal temperature and pressure gradient over south Asia south of Lat 25°N in the layers between 600 and 300 mb and that this reversal acts like a switch for the atmospheric circulation over the southern half of Asia producing the 'burst of monsoon' over the west coast of India. However, this view has been questioned by subsequent workers (Narayanan, 1963; Koteswaram and Bhaskara Rao, 1963; and Ananthakrishnan, 1965) in view of the fact that when the monsoon first sets in, the subtropical anticyclone in the upper atmosphere — the region of highest pressure and temperature — is well to the south of Tibetan Plateau.

2.11 In another paper Flohn (1965) has pointed out that the rapid displacement of the subtropical jet to about 40°N at the time of onset of the monsoon, coincides with a rearrangement of the quasipermanent troughs - just upstream and downstream of the Tibetan block. One of the two troughs named "The Pamir trough" is near 65°E and the other called a "west Chinese or Szechwan trough" is at 100-105°E.

2.12 From a study of the upper wind and temperature data over the Mediterranean and Middle East area for the period 1949-1953, Sutcliffe and Bannon (1954) drew attention to an interesting association between the dates of appearance of the first easterlies at 200 mb level over Aden and the dates of onset of the southwest monsoon over Kerala. They found that the first easterlies at 200 mb level appeared over Aden five to sixteen days earlier than the corresponding dates of onset of the monsoon over Kerala. They have remarked that a careful study of these changes might be useful for predicting the summer monsoon over South India. Following up this suggestion Ananthakrishnan and Ramakrishnan (1965) examined the changes in the zonal winds at 200 mb level over the Indian stations in India and the middle-east stations of Aden and Bahrain for the years 1958 to 1964. They found that changes similar to these noticed by Sutcliffe and Bannon over the middle-east stations also occur at the Indian stations near about the same latitude. For each of these stations there were two dates A and B which correspond respectively to establishment of steady easterlies. During the interval between A and B easterlies and westerlies alternate. This interval showed fluctuations in different years ranging from zero to as much as a fortnight in some years. The seven year period 1958-1964 covers years of early, normal and delayed onset of the southwest monsoon. In 1958, the easterlies first appeared over Aden nearly eight weeks before the onset of the monsoon on the Malabar coast which was delayed in this year by a fortnight. In 1964 easterlies were noticed over Aden nearly a month before the onset of the monsoon. On the other hand in 1960 when the monsoon set in on the Malabar coast a fortnight before the normal date, the easterlies appeared over Aden almost simultaneously. Thus, although the zonal wind changes at 200 mb level give some prior indication of the onset of the monsoon they have little forecasting value.

2.13 Koteswaram (1958, 1960) and also Koteswaram and Bhaskara Rao (1963), drew attention to the setting in of an easterly jet stream at low latitudes over south India which coincided with the "burst" of the monsoon there. Koteswaram considered the upper divergence associated with the "left exit" sector of the easterly jet induced convergence in the lower levels and the subsequent burst of the monsoon over the southwest coast of India. Discussing the "burst" of the monsoon over west coast in 1958, he found an upper trough in easterlies at 80°E and the divergent southward meridional flow apparently induced a "low" in the lower levels off the southwest coast of India during the second week of June. Like Riehl, he also preferred to locate the monsoon trough at 700 mb level.

2.14 Ramamurthy and Keshavamurthy (1964) studied the flow patterns at the 500 and 300 mb levels associated with the onset of the monsoon over Kerala. They found that the onset of the monsoon is associated with the sudden northward shift of the Arabian Sea subtropical anticyclone and its establishment over West Pakistan and adjoining areas of Iran particularly at the 300 mb level. At the 500 mb level, in addition to similar changes, the monsoon trough also forms over the Kerala coast simultaneously.

2.15 Ananthakrishnan and Ramakrishnan (1966) found that in the years in which the onset of the monsoon was normal or delayed, there was a sudden weakening of the upper tropospheric westerlies over north India at the time of the onset and strengthening of the upper tropospheric easterlies over south India one or two pentads thereafter. In the years in which the onset was early the

the onset and the easterlies over south India gained strength only subsequently. The shift of the upper tropospheric subtropical anticyclone from its winter location over south India to about 20°N is nearly simultaneous with the onset of the monsoon rains over the south of the Peninsula.

2.16 Ramamurthi and Jambunathan (1966) found the weakening of westerlies, northward shift of upper tropospheric west wind maximum over north India and the appearance of strong upper easterlies over extreme south Peninsular India are not pre-requisite conditions for ushering in the monsoon rains. According to them, available evidence indicates a close connection between the establishment of the Northern Hemisphere near equatorial trough over Kerala between 700 and 400 mb in association with a mid-tropospheric vortex and the onset of the monsoon.

2.17 Natarajan Pillai (1960) found that both the onset and the further advance of the monsoon current are to a great extent governed by cyclonic and anticyclonic vortices at 700 mb level.

2.18 Thiruvengadathan (1966) using Trivandrum data for the years 1956-65 found that westerlies slowly increase in depth and extend to about 1.5 km about three pentads before the onset of the monsoon. During one or two pentads preceding the onset, the westerlies extend to about 6 km. The upper tropospheric easterlies attain a speed of about 40 kt at the time of onset. The speed continues to rise for another two pentads reaching 60 knots or more.

2.19 Pant (1964) has investigated the pentad patterns at the 700 mb level in association with the onset of the monsoon. He found that the onset of the monsoon over India and the adjoining seas south of Lat 15°N is associated with the disappearance of the premonsoon 'high' over the central parts of the country and the formation of the monsoon trough near 90°E at 700 mb level. The first disappearance of the high from the central parts of the country (as signified by the disappearance of 3140 gpm contour from over the region) and the southward extension of 3120 gpm contour as far south as 10°N, indicating the formation of monsoon trough signify the onset of monsoon over India and adjoining seas south of about 15°N. Monsoon sets in over central parts of country with the disappearance of the anticyclonic curvature of 3120 gpm contour over the region.

2.20 Pant and Jennekar (1961) examined the onset of the monsoon during the years 1957-59 using the 850 mb level data. They found that in the south the onset of monsoon does not result in any conspicuous change in the temperature and humidity of the air stream. The only characteristic change is the setting in of westerlies which are extremely steady and which can normally be separated from the winds existing earlier. Further north, especially at the interior stations, there is a conspicuous change in the thermal properties accompanied by rise in humidity.

2.21 Ananthakrishnan and Thiruvengadathan (1968) examined the manner in which thermal gradients across India reversed both in space and time, in association with the onset of the southwest monsoon. For this purpose 10-day mean zonal winds at the standard reporting levels over Trivandrum, Nagpur and New Delhi for the six year period 1961-66, were made use of and vertical shears between adjacent levels worked out. If the winds are geostrophic, the vertical shears of the zonal winds will be directly proportional to the meridional temperature gradients. The study led to the following inferences:-

(i) the onset of the monsoon rains at each of the three places takes place when the meridional thermal gradients have reversed at all tropospheric levels between 200 and 700 mb; and

(ii) the reversal starts in the upper troposphere about six weeks before the onset of the monsoon rains and progresses downwards; the reversal between 700 and 500 mb takes place last almost simultaneously with the onset of the monsoon rains.

2.22 It will be seen that in all these studies workers have generally focussed attention on individual aspects of the transition in the circulation features from winter to summer leading to the onset of the monsoon. Apart from the well-known indications on the surface and lower tropospheric levels, of the arrival of the monsoon (vide p. 11 of Appendix I of FMU, Rep. No. IV - 18.1) the other parameters that have been studied in more recent years are:-

(i) strength and depth of the lower tropospheric monsoon westerlies;

(ii) moisture content in the lower troposphere;

(iii) middle tropospheric circulation - such as the east-west trough at 700 mb levels, cyclonic vortices at 700-500 mb levels, collapse of the anticyclone at 700 mb level over north Peninsula; and

(iv) upper tropospheric features such as the shift of the stream westerlies

3. Surface Synoptic Features

3.1 The advance of the monsoon over the sea areas and along the coast is usually accompanied by squally weather, rough seas, long heavy swell and heavy rain-showers. Very often ships in the area of the advancing monsoon current report winds of strength 20/40 kts from SW/W. The severity of the weather varies from year to year.

3.2 The advancing monsoon current is usually associated with some form of disturbed weather over the Arabian Sea/Bay of Bengal. There is a pronounced tendency for the formation of low pressure systems at the leading edge of the monsoon current, and it is not uncommon for some of them to develop into severe cyclonic storms. At and near the time of onset of the monsoon along the west coast, a trough of low pressure over the southeast Arabian Sea is a feature often noticed on the surface chart. The monsoon may also advance along the west coast in association with disturbances that form in the Bay of Bengal. The synoptic situations near about the dates of onset of the southwest monsoon along Kerala coast collected from the departmental weather reports for the period 1901 to 1968 are given in Appendix I.

3.3 The data in Appendix I have been made use for compiling Table I given below:

Table I.

Synoptic features in the Arabian Sea/Bay of Bengal at the time of onset of the Southwest Monsoon (1901 - 1968)

(Percentage frequencies of occurrences)

Nature of system	Low Pressure System in			No significant system either in A or B.
	A and B	A only	B only	
T	17	18	19	25
D	2	3	6	
S	4	4	4	
Total.	22	24	28	25

A = Arabian Sea; B = Bay of Bengal;

T = Trough, unsettled conditions, low pressure area etc. D = Depressions; S = Cyclonic Storm

west monsoon is associated with synoptic disturbances in the Arabian Sea/Bay of Bengal. By far the most common situation is a weak system like a trough of low pressure. There are quite a number of occasions when the monsoon sets in over south Arabian Sea and South Bay of Bengal simultaneously. Hence after May 1, even feeble systems in the Arabian Sea and the Bay of Bengal, which are likely to increase the depth of westerlies over the extreme south of the Peninsula and cause appreciable weather should be carefully watched. During this period reports from ships in south Bay and south Arabian Sea showing strong winds from any westerly or southerly direction, squalls, thunderstorms, rain or high waves and long swells should be taken as possible precursors of the monsoon.

3.4 In the beginning of May, the pressure gradient over the Arabian Sea is weak, with isobars running parallel to the west coast, so that nearly the same pressure value obtains at Bombay and Trivandrum. In early May, on individual days, the gradient over the Arabian Sea may even be from north to south, with a weak high still persisting over north and central Arabian Sea. However the configuration changes with advance of the season and towards the end of May the isobars take a west-east orientation, with pressure increasing towards north. Fig 1 illustrates the north-south variation of pressure and pressure gradient across India from the beginning of April to the end of June. The three stations - Trivandrum, Bombay and Jodhpur - have been chosen to illustrate the variations representative of conditions over the extreme south, the centre and the north of the country respectively. At Trivandrum which is closest to the equator the pressure gradually falls from the beginning of April to the middle of May by 2 mb and thereafter slowly increases. At Jodhpur close to the seasonal heat low, there is a steady fall of pressure from the beginning of April to the end of May at the rate of 1 mb per week. The difference of pressure between Trivandrum and Jodhpur which is about 1 mb at the beginning of April becomes 8 mb about the time of onset of the monsoon. The pressure difference between Trivandrum and Bombay also registers a steady increase from the first week of May till the first week of June. The figure shows that at the time of onset of the monsoon over Kerala the pressure difference between Trivandrum and Bombay is slightly less than that between Bombay and Jodhpur, the numerical value being about 3 mb. A pressure rise at the southern stations like Colombo, Trivandrum or Minicoy with a fall at the stations

ficant feature of the monsoon circulation. It is, therefore, of interest to examine the intensity of the heat low at the time of the onset of the monsoon. For this purpose the pressure value at Jacobabad (near the centre of the heat low) at the time of onset of the monsoon over Kerala was examined. Since moving disturbances may produce large fluctuations in pressure values, the smoothed values obtained by taking seven day means centred on the date of onset were utilised. Analysis of the data for the period 1901 to 1960 is given in the following table.

Table 2.

Percentage frequency distribution of Jacobabad pressure at 0300 GMT

Pressure in mbs.	997	998	999	1000	1001	1002	1003	1004
Percentage frequency	7	9	16	23	20	11	11	3

The pressure value in the heat low is 1001 mb or less at the time of the onset of the monsoon on 75% of the occasions.

4. Moisture Field

4.1 The monthly mean values of precipitable water (w) and rainfall (R) for Trivandrum (Ananthakrishnan et al 1965) are given below:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
w(gm)	3.29	3.34	3.55	4.38	4.81	4.57	4.42	4.55	4.52	4.54	4.65	3.64
R(cm)	2.0	1.9	3.9	11.6	22.3	33.5	19.7	12.0	11.3	27.3	17.7	6.3

It will be seen that there is not much variation in the total moisture content of the atmosphere over Trivandrum during the months April to November. Notice that the moisture content is slightly more in May than during the monsoon months June to September. Comparison of the moisture content with the rainfall figures brings out that despite the near constancy of the moisture content the rainfall shows considerable variation. The increase in rainfall with the onset of the monsoon is brought about by changes in circulation features leading to increased vertical motions and not due to any increase in moisture content of the atmosphere.

4.2 Mukherji (1962) computed the amount of precipitable water in the atmosphere over Trivandrum for the period 15 May to 15 June for ten years and found that

(i) there is no marked build up of the precipitable water in the atmosphere

(ii) the maximum moisture content in the atmosphere is not generally reached on the dates of the onset of the monsoon.

4.3 The departmental Forecasting Officers' Conference (1960) considered the criteria to be used for declaring the onset and withdrawal of the monsoon. The sub-committee which went into the question was of opinion that "one factor which is found to be fairly significant and applicable to all parts of the country is an appreciable change in wet bulb potential temperature in the atmosphere upto about 5000 ft or so with the advent of the monsoon." The committee, therefore, recommended a further examination of the problem. Pant and Warnekar (1961) who made a detailed study on this aspect found that at Trivandrum the wet bulb potential temperature at 850 mb level does not show any significant change from pre-monsoon to monsoon. At Bombay they found a gradual change but this was not very helpful for fixing the date of onset unambiguously. Similar analysis of wet bulb potential temperature over Trivandrum for 700 and 600 mb levels also showed no significant changes at the time of onset of monsoon.

5. Wind Field over South Peninsula

5.1 The onset of the southwest monsoon marks the transition from the winter to the summer type of circulation over South Asia. During the greater part of May winds over Trivandrum are light to moderate westerlies upto 1.5 km: above this level upto 12 km the steadiness of the wind decreases. With the onset of the monsoon, the westerlies of the lower troposphere increase in depth as well as in strength and steadiness. The westerlies are over-lain by an equally steady easterly current in the upper troposphere. The monsoon westerlies are strongest at 1.5 to 2.0 km while the upper easterlies reach their maximum strength at about 14 km. The transition between the easterlies and the westerlies occurs generally between 6 and 7 km.

5.2 To illustrate the changes in the wind field over the extreme south Peninsula at the time of onset of the monsoon, vertical time sections of the zonal winds over Trivandrum from 1 May to 30 June were prepared for the years 1958 to 1967 (Figs 2(i) to 2(x)). The data relate to 1200 GMT, supplemented by the 0000 GMT observations where 1200 GMT data was lacking. The isopleths have been drawn at 10 kt interval upto 40 kt and at 20 kt interval for higher

these figures. An examination of these diagrams brings out the following:-

(i) Deepening of the lower tropospheric westerlies:

At the time of onset of the monsoon (including temporary advance) the depth of the westerlies increases from 1-2 km to 6-7 km. This deepening takes place either on the day of onset of the monsoon, or a day or two earlier. In 1960 and 1967 (temporary advance) the deepening of westerlies occurred a day after the monsoon had set in. (The year 1961 was peculiar. The deepening of the westerlies noticed over Trivandrum during the second week of May this year is due to the southward extension of the middle latitude westerlies and is not to be associated with the monsoon).

(ii) Strengthening of the lower tropospheric westerlies:

The westerly current also strengthens to about 20/25 kt in the lower troposphere within a day of the onset of the monsoon and on some occasions 2 or 3 days later; occasionally it may also strengthen even two days prior to the onset. Subsequently the winds strengthen further to 30/40 kts.

(iii) Strengthening of the upper tropospheric easterlies:

On most occasions the upper easterlies at 14 or 16 km had reached 40 kts during the week preceding the date of onset of the monsoon. Only on very few occasions they were below 40 kts. On or near about the date of onset, the easterly wind at Trivandrum reached maximum speed of 60 kts and above in most of the years.

(iv) Organization of the wind flow:

The organization of the wind pattern to the typical monsoonal type (viz westerlies upto about 6 km with easterlies above) is spread over a period of two weeks or more. While the increase in depth of the lower tropospheric westerlies and their strengthening occur invariably in a rather abrupt manner during the course of two or three days, the upper tropospheric easterlies which appear only at very high levels (at 14-16 km) in the beginning descend to lower levels and strengthen more gradually. The entire organization is spread over a period of a few weeks.

(v) Fluctuations of the westerlies:

After the onset of the monsoon the westerly depth does not normally go below 3 km. After a temporary advance, a decrease in the depth of the

ted with strong monsoon conditions (in terms of rainfall) and a weak and shallow westerly field with weak monsoon.

5.3 As the diagrams illustrate there is close relationship between the wind field and the rainfall pattern over south Peninsula at the time of the onset of the monsoon. Changes in the wind field thus give useful indications to the forecaster for anticipating the onset of monsoon one or two days in advance.

6. Upper Air Conditions over North India.

6.1 The passage of western disturbances over extreme north India and the strength of upper westerlies over north India may be thought of as indices of the activity of the westerly winter regime. Some meteorologists are, therefore, inclined to the view that the persistence of the winter type westerly regime in the northern India inhibits the advance of the southwest monsoon in the extreme south India. It is also, at times, stated that if the activity of westerly disturbances in April and May is high and the disturbances take a more southerly course the onset of the monsoon will be delayed. This view is also implicit in the work of Yin and Yeh who associated the burst of monsoon over India-Burma area with the shift of the westerly jet stream to the north of the Himalayas; Lockwood (1963) has also arrived at a similar conclusion.

6.2 To examine the validity or otherwise of this idea, the summaries of weather included in the Indian Daily Weather Reports for the years 1951 to 1968 on the dates of onset of the monsoon and one day earlier and later, were looked into. It was found that in a little more than half the number of years western disturbance activity over northwest India and West Pakistan was still persisting at the time of onset of the monsoon over Kerala. This can be so even in years of late onset of the monsoon. Hence the cessation of western disturbance activity is not a pre-requisite for the onset of the monsoon. Pisharoty and Desai (1962) have also stated that Yin's suggestion that monsoon bursts over India-Burma area only when the western disturbances cease to travel along the southern periphery of the Himalayas, is not borne out by observations.

tion of the winds over New Delhi (lat. 28.5°N) at 9.0, 10.5, 12.0 and 14.1 km a.s.l. has been made for the years 1955 to 1967. With reference to the dates of onset of monsoon as given in the departmental weather reports, it is seen that wind speeds during the week before the onset, have ranged from 30/40 knots to 70/80 knots in the different years. During the onset there has been a weakening in 9 years out of the 13 years, the weakening having been appreciable in some years (eg. 1960 and 1963). In the other four years the speeds either remained of the same order (eg. 1962) or strengthened (eg. 1964). In the week following the onset, the westerlies have either weakened further or continued to have the same speeds. The winds for three typical years (1963, 1964 and 1966) are depicted in Fig. 3.

6.4 The upper tropospheric winds over Bombay (lat. 19°N) have also been examined for the period 1955-67 to see whether any significant changes occur in association with the onset of the monsoon over Kerala. With reference to the departmental dates of onset, it is seen that during the week before the onset of the monsoon, upper tropospheric winds over Bombay are mostly westerlies 10/20 kt. During the onset these change over to easterlies, the actual reversal taking place either during the onset or immediately thereafter. In some years this reversal occurs well before the onset of the monsoon. These changes are somewhat similar to these observed by Sutcliffe and Bannon over Aden.

6.5 On account of the north-south meandering of the west wind maximum, as well as the split of the west wind maximum into streaks, analysis of longitudinal cross-sections over the whole of north India was made to get a more complete picture of the changes that take place in the westerly wind regime at the time of onset of the monsoon. Figs 4(i) to 4(xi) depict cross-section charts for the eleven years 1958 to 1968 prepared utilising pentad values of winds (scalar values) at 200 mb level for stations to the north of lat. 20°N over India between 70°E and 80°E. Karachi and Peshawar observations have also been used when Jodhpur and Srinagar did not have sufficient number of observations.

6.6 In the years 1961, 1962 and 1965 the westerly maximum was well to the south of the seasonal position (about 29°N) in the pentads preceding the onset [illegible], the west wind maximum either shifted northward from its earlier position or weakened at the time of onset of the monsoon. This occurred either a pentad earlier than the onset or during the same pentad in which the onset occurred. An integrated picture of the pattern of changes in the westerlies at the time of onset of the monsoon can be obtained only by considering the entire wind field over the north India averaged over a period of a few days for more than on level instead of confining attention to a single station, day or level.

7. Satellite Data

7.1 Krishna Rao (1966) made a study of the onset of monsoon over India during 1962 using data from channel 2 (10-13 microns) of TIROS IV meteorological satellite, and concluded that "the centres of low outgoing long wave radiation values associated with the cloudiness of ITC moved northward with time. With the advancement of the cloudiness northward the monsoon set in over the Indian sub-continent". Since the launching of the operational satellites carrying the APT system in the beginning of 1966, cloud-cover information over India and the adjoining sea areas is being regularly received through the APT ground station at Bombay. Ramamurthi and Janbunathan (1967) studied the clouding in the Indian Sea areas shown by satellite pictures at the time of onset of monsoon in the year 1966 and found that the onset of the monsoon in Arabian Sea and Bay of Bengal is mainly associated with developments taking place to the north of the equator and their extension northward into the Indian area. There is no movement of cloud systems from the southern hemisphere into the northern hemisphere at the time of monsoon onset. With the data now available for more number of years, the sequence of cloud cover over the Indian Sea area was examined for the period of the onset of the monsoon over the extreme south India during 1966, 1967 and 1968.

7.2 Daily averages of cloud amounts over every two and a half degrees square were estimated from the satellite pictures. Time-latitude sections of the mean cloudiness over the sea area (60°E to 80°E) for the period 1 May to 30 June for the two years 1967 and 1968 are shown in Fig. 5. The significant results of the analysis (Ananthakrishnan, Srinivasan, and Janbunathan 1968) are :

(i) there is a progressive northward movement of organized cloud maximum from equator to 20°N during the period of the onset of the monsoon over extreme south Peninsula and its progress northward;

(ii) the organization of the cloud maximum in the near equatorial region of the northern hemisphere and its northward shift commences some days before the date of onset of the monsoon over Kerala;

(iii) the mean clouding over the Arabian Sea area in the latitude of Kerala (7 1/2°N to 10°N) reaches 2 to 3 oktas about a week prior to the onset of the monsoon over Kerala and progressively reaches near overcast conditions at the time of onset over Kerala;

(iv) As the monsoon advances northward along west coast, there is a relative decrease in the cloud amount near the equator.

The study indicates that in the month of May, any moderate to heavy clouding in the near equatorial regimes which shows some tendency to persist and shift northward may be a precursor of the onset of the monsoon over Kerala.

8. Synoptic Situation on Days of Onset of Monsoon in Selected years

8.1 The conditions in the surface and upper air at the time of the onset of the monsoon are described in detail in this section for the following six years:

Year	Date of onset	
1957	1 June	Normal
1966	1 June	
1960	14 May	Early
1962	17 May	
1964	6 June	Late
1968	6 June	

8.2 The dates given above have been taken from the published weather reports of the Department. These dates are practically the same as the revised dates as per FMU Rep. No. IV-18.1. The years chosen relate to the IGY and post IGY period because of the denser network of upper air stations in recent years. The following charts and diagrams are presented for the above dates:-

(i) Surface isobaric chart for 0300 GMT

(ii) [illegible]

(iv) Vertical time-section for Trivandrum for the week centred on the date of onset

(v) Longitudinal section from Gan to Srinagar.

8.3 1957 — Date of onset: 1 June (Figs 6(i) to (iii))

8.3.1 Surface features: By the morning of 30 May, a trough of low pressure developed over the Laccadives and off Kerala coast. During the preceding 24 hrs there had been widespread rainfall in Kerala and Arabian Sea Islands, many stations reporting thunderstorms. Minicoy received 8 cm and Colombo 7 cm. Since 1200 GMT of 29th, ship and island observations indicated heavy clouding, rain or thundershowers in the whole Arabian Sea south of Lat. 10°N. The trough over Laccadives persisted for the next two days with a slight northward shift in its position. Ships observations in the Arabian Sea south of 10°N showed windspeeds increasing to about 20 kts, with persistence of heavy cloudiness and rain or thundershowers. Along the Somalia coast winds were southwesterly 30/35 kts. By 1st June 1200 GMT squalls were also reported by ships. Fairly widespread rain or thundershowers with a few heavy falls were reported from Arabian Sea Islands, Kerala and Ceylon on 31st May and 1st June. The observations from Male for 29 May showed a pressure gradient of 3-4 mb over Comorin-Maldives region. On 1st morning the pressure gradient between Minicoy and Bombay was 3 to 4 mb. A western disturbance moving across the Punjab on 1st had caused fairly widespread thunderstorm activity over Kashmir, Punjab and West Uttar Pradesh Hills. The pressures were below normal over the whole country and 2-3 mb in defect over northwest India and West Pakistan; the 24 hour changes were generally positive over the area.

8.3.2 Upper air features: By 30th the winds over Minicoy and south Kerala backed to westerly and strengthened to 20-30 kts upto 1.5 km. During the next 48 hours these westerlies strengthened further in the lower levels and also reached a depth of about 6.0 km. The upper winds were 30 to 40 kt over Delhi at 300 mb level. (Items iv and v are not presented due to poor data)

8.4 1966 — Date of onset: 1 June (Figs 7(i) to (v))

8.4.1 Surface features: Towards the last week of May reports from ships in the south Arabian Sea showed increase in cloudiness accompanied by showers and thundershowers. By 30th the winds over 04°N-15°N kt in the Arabian Sea

low on June 1 over Central Bay and the monsoon had advanced into the Bay south of Lat. 14°N where ships reported winds from SW/W speed 15/25 kts and heavy clouding. A ship at 11°N 61.5°E reported WSW-20 kts and rain at 1200 GMT of 1st. Minicoy reported continuous rain at 0300 GMT and westerly 10 kt while at 1200 GMT the same station reported westerly 25 kt and gusty. Further south towards the equator ships reported generally southerly winds of 5/10 kt and lightly clouded skies. 24 hours pressure changes on the morning of June 1 were negative (1.0 to 1.5 mb) along Kerala coast and Laccadives with pressure rising to the south. Pressure departures were also negative (1 to 1.5 mb) over the area. Precipitation of 4 to 5 cm associated with thunderstorms had occurred in the Arabian Sea Islands; light showers had occurred along the Kerala coast. The pressure gradient over East Arabian Sea which was very slack on June 1 showed steady increase during the next two days, and on 3rd morning the pressure difference between Minicoy and Bombay reached 3.0 mb. The seasonal low was over Sind-Baluchistan. Pressures were rising over the whole of north India and were 3-6 mb above normal over northwest India on June 1.

8.4.2 Upper air features: On the morning of June 1 winds were about 30 kt upto 0.6 km over Ceylon. Winds over south Kerala, though light, had a westerly component upto 3.6 km. The low in the Bay was the dominant feature in the upper levels also and the associated circulation was seen upto 7.2 km. The westerlies over the Arabian Sea Islands and the extreme south Peninsula strengthened and deepened during the subsequent 24 to 36 hours. Although the upper tropospheric westerlies over north India were strong, the belt of maximum westerlies had shifted north and Srinagar was reporting the highest wind speed (85 kt) compared to Delhi where it was of the order of 50 kt. A feeble trough in westerlies was also moving across Kashmir. The upper easterlies over extreme south Peninsula had organized and strengthened to over 40 kt at 14 km even by 25th and the maximum speed in the easterlies were of the order of 70/80 kt by 27th. At 200 mb level the sub-tropical anticyclone had reached 20°N. Thus the high level conditions over India had definitely changed to the summer type.

8.5 1960 — Date of onset: 14 May [Figs 8(i) to (v)]

8.5.1 Surface features: A depression which formed over Laccadives on 10 May moved northwest-wards, intensified into a cyclonic storm and was centred on the morning of 14 near 15°N and 64°E. On this day a well-marked trough of low pres-

Arabian Sea; since the cyclonic storm was the dominant system, the isobars in the east Arabian Sea were generally from SW to NE and the pressure gradient between Minicoy and Bombay was hardly 1.0 mb. Ships in the Arabian Sea to the south of Lat. 10°N reported mainly southwesterly winds 10/15 kts, a number of them reporting showers and rain. Along the west coast to the south of Mangalore and over Arabian Sea Islands widespread rainfall was reported most of them being associated with thunderstorm. The pressure changes along west coast and Arabian Sea Islands were negative (0.5 to 1.0 mb). In the north the seasonal low was well marked over northeast Baluchistan under the influence of a western disturbance and there was rather steep pressure gradient over Baluchistan, Sind and West Rajasthan. The pressures were still falling there and the maximum negative pressure departure over the area was about 4 mb.

8.5.2 Upper air features: On the 14 morning the upper winds were generally moderate westerlies below 2.1 km along the west coast upto Mangalore. The trough in the southwest Bay was more pronounced in the upper levels upto nearly 6.0 km. The westerlies increased in depth but strengthened only subsequently over Kerala. At 500 mb level an eastward moving trough in westerlies was extending from Afghanistan to Sind. Over north India upper westerlies were strong, the maximum wind being of the order of 70-80 kts. The upper easterlies over the extreme south Peninsula did not exceed 40 kts. The vertical section along 75°E clearly shows that at this time, the westerly jet was still over Delhi-Jodhpur area and the easterly jet had not organized itself over the extreme south Peninsula. At the 200 mb level the ridge line was still near about latitude 15°N. Thus the upper tropospheric conditions were still akin to winter type circulation.

8.6 1962 — Date of Onset: 17 May [Figs 9(i) to (v)]

8.6.1 Surface features: On 17th surface chart a depression lay over north Kerala and adjoining areas. This was the remnant of a cyclonic storm which crossed the coast near Cuddalore in the early hours of the 16th. Pressures were falling over Kerala by 2 to 3 mb during the past 24 hours. The departures were 4 to 5 mb negative. Ships in southeast Arabian Sea and Comorin area and the Arabian Sea Islands were reporting westerly 20/25 kt, heavily clouded skies and rain. The pressure gradient between Amini Divi and Male was about 4 mb and between Bombay and Minicoy [illegible]

[illegible] amounts ranging from 7 cm to 14 cm. The character of precipitation over Kerala was of rain or drizzle type as shown by the present and past weather reports compared to the previous day when it was predominently thunderstorms. The precipitation which also extended northwards along the Mysore - Konkan coast was associated with thunderstorms. The low over northwest India had also been intensifying (note the 24 hr. pr. fall of 4 mb over the area) and the pressures there were below normal by 2 mb.

8.6.2 Upper air features: The cyclonic circulation associated with the depression over Kerala extended to about 200 mb (12 km) level with the winds over Kerala, Arabian Sea Islands and Ceylon being strong West/Northwest (25/30 kts) upto 9.0 km. At 200 mb level the subtropical ridge line over the Peninsula was near 18°N to 19°N, having shifted from its location near 13°N on 12-13 May. There was a general strengthening of the upper easterlies during the previous week. The upper tropospheric westerlies in north India continued strong with the maximum winds of the order of 80 kt. A westerly trough was also affecting Kashmir. As will be seen from the longitudinal cross section westerlies in upper India were strong at the time of onset of the monsoon.

8.7 1964 — Date of Onset: 6 June [Figs 10(i) to (v)]

8.7.1 Surface features: On the morning of 5 June ships in Maldives-Comorin area reported westerly winds of speed 20/25 kt with rain and waves of height about 2 metres. By the evening the pressures were falling over the whole country. The 24 hour pressure changes were of the order of 1.5 to 2.5 mb along the north Kerala coast and Laccadives area. On the next morning a trough of low pressure was seen on the surface chart off the Mysore coast and overcast skies with rain were reported by stations in Laccadives and along Kerala coast. During the past 24 hours widespread rain had fallen in the Peninsula south of Lat. 13°N, in Laccadives and West Ceylon, with amounts 4 to 8 cm at a number of places. The pressure gradient between Minicoy and Bombay was 4.1 mb on 6 morning. The 24 hour changes were positive over the south Peninsula and Laccadives and negative to the north suggesting a northward displacement of the trough. Pressure departures were positive over Indian Peninsula and Ceylon. The central pressure in the 'heat low' was of the order 999 mb, 1-2 mb above normal. A western disturbance was causing isolated were from northwest to north, 15/25 knots. During the course of the next 24 to 36 hours, they backed to SW/W and slightly strengthened over Ceylon and the extreme south Peninsula and Laccadives. The westerlies over this area extended upto 4.5 km. A cyclonic circulation could be seen over Laccadives between 700 and 500 mb levels on 6th evening. The upper easterlies over Trivandrum began strengthening by 29 May and the speeds reached 90 knots on 31st evening; thereafter the upper easterlies continued strong and the maximum strength of the easterlies over the south Peninsula ranged between 60 and 80 kt during the first week of June. A deep trough in westerlies was moving across West Pakistan on 2nd at 500 mb level and aloft; by 5th the trough had moved to western Himalayas and flattened. The westerlies were strongest (95 knots) over Srinagar on the 4th; on 6th upper winds over Delhi were about 50-70 kt between 400 and 150 mb levels; the core of the westerly was probably shifting to the north of Delhi. Thus during this year at the time of onset of the monsoon, the upper easterlies were strong and the westerly maximum was getting displaced northward from Delhi.

8.8 1968 — Date of onset: 8 June [Figs 11(i) to (v)]

8.8.1 Surface features: Over southeast Arabian Sea ships and Island stations reported west/northwest winds of speed 10/15 kt on 5th and 6th. They backed to westerlies by 6th evening and convective activity increased over the area on 7th. There was a sharp increase in thunderstorm activity over Kerala on 7th. On 7th and 8th ships reported generally wind of 10-15 kt over south Arabian Sea and about 20 kt over south Bay. A feeble trough lay off north Kerala-Mysore coasts on 8th. The pressure difference between Minicoy and Bombay on 8th was 2.6 mb. The heat low over West Pakistan was intensifying; the lowest pressure on the 8th was 995 mb. The maximum pressure change over Kerala was about -2 mb on 8th morning and the departures were generally indifferent.

8.8.2 Upper air features: In the lower troposphere the winds over Ceylon strengthened to 30/35 kts on 5th morning. The winds over Kerala and Arabian Sea Islands backed from northwest to west between 7th and 8th. By 7th evening the depth of westerlies increased to about 7.2 km over the extreme south Peninsula and on 8th, the winds upto 700 mb were about 10/15 kts. A trough

[illegible] ing which moved inland on the 7th and persisted there for the next two days. The subtropical ridge line at 200 mb which was along 19-20°N on 1st June shifted to 23°N by 7th. The upper tropospheric westerlies were generally 20-40 kt over north India during the week preceding the date of onset and weakened further to 10-20 kt on the eve of the onset. The wind over Srinagar were also only 30-40 kt at 200-150 mb level on 7th and 8th. The upper tropospheric easterly maximum over the south Peninsula and Ceylon was 50-70 kt between 1st and 8th June. There was a slight strengthening of the upper easterlies near about the time of onset.

8.9 The six instances of synoptic features at the time of onset of the monsoon discussed in this section — two cases each of normal, early and delayed onset — show that despite some broad similarities large differences exist in the details from one year to another not only between years of early and late onset but even among years of early, normal or late onset. A low level disturbance in the Arabian Sea or the Bay of Bengal is noticed in many years. The strengthening of the upper tropospheric easterlies over the south Peninsula can occur a few days before the onset of the monsoon; similarly in some years the upper tropospheric westerlies over north India can continue to be strong for a few days after the onset of the monsoon over Kerala. The strengthening and deepening of the lower tropospheric westerlies over the southern stations appears to be the most useful guide for anticipating the onset of the monsoon a day or two in advance.

9. Conclusion

9.1 In the preceding sections we have seen in detail the various surface and upper air conditions over India near about the time of the onset of the monsoon over Kerala. In so far as land areas are concerned, the word "monsoon" has been accepted to connote the rainfall and not the primary circulation feature. It has been shown in section 5, that the features of the circulation (wind field) - such as the abrupt strengthening and deepening of the westerlies, the organization and strengthening of the upper easterlies-are also nearly synchronous with rainfall. Thus it is possible to detect in the wind field also some indications of the onset of the monsoon rainfall.

9.2 We have seen the moisture over Kerala is quite plentiful much before the monsoon sets in. Hence a triggering mechanism to release the preci[illegible] and eventually establish the typical wind field is what is needed. Thi triggering mechanism is provided by some form of disturbance in the Bay of Bengal or the Arabian Sea.

9.3 From the forecasting point of view the following may be taken as the synoptic indications in the months of May/June for the imminent onset of the monsoon over Kerala:-

i) Any disturbance in the Arabian Sea/Bay of Bengal. The most common initial form of the disturbance is a trough of low pressure in south-east Arabian Sea.

ii) Reports from ships and island stations in the south Arabian Sea, of heavy convection, squally weather and rough seas or swell from south-west with moderate to strong winds from some southerly or westerly direction.

iii) The strengthening and deepening of lower tropospheric west winds over extreme south Peninsula and Ceylon and strengthening of upper tropospheric easterlies to 40 kts for a few days at 14 to 16 km; at the time of onset the easterlies reach a maximum speed of about 60 kt.

iv) The tendency of the strong westerlies of the upper troposphere over north India to break up or to shift northwards;

v) Persistent moderate to heavy clouding in the south Arabian Sea shown by satellite pictures and its tendency to shift northwards.

9.4 Although these observations are indicative of the imminent commencement of the monsoon rains, it is not necessary that they should be simultaneously present on all the occasions. The reorganization of circulation from the winter to the monsoon pattern extends over an interval ranging from a few days to one or two weeks. As such it is difficult to define a unique date as the "date of onset of monsoon". However, there is a need to define such a date for operational purposes. This has to be done primarily from considerations of rainfall which, of course, implicitly take into account the circulation features (vide FMU Rep. No. IV - 18.1). Forecasters in operational offices have to give advance information about the onset of the monsoon and issue appropriate warnings. This report is intended to provide the necessary background and guidance material for this purpose.

REFERENCES AND SELECTED BIBLIOGRAPHY.

1. Ananthakrishnan, R. 1965: General circulation of the Atmosphere over the Indian Ocean and adjoining areas. Proceedings of the Symposium on Meteorological Results of the I.I.O.E. p. 105.

2. Ananthakrishnan, R. and Ramakrishnan, A.R. 1965: Upper tropospheric zonal circulation over India and neighbourhood in relation to the Southwest Monsoon. Proceedings of the Symposium on Met. results of the I.I.O.E. pp. 415-422.

3. Ananthakrishnan, R. and Ramakrishnan, A.R. 1965: Transition from winter to summer circulation over the Asian Monsoon region (Unpublished). Presented at the Fourth Tech. Conference on Hurricanes and Tropical Meteorology, Miami, U.S.A.

4. Ananthakrishnan, R. and Rangarajan, S. 1963: Inversions and stable layers in the free atmosphere over India-Part I. Ind. Journ. Met. and Geophys., Vol. 14, No. 2, p. 173.

5. Ananthakrishnan, R., Srinivasan, V. and Jambunathan, R. 1968: Study of the onset and advance of the Southwest Monsoon over the Indian Peninsula utilising satellite cloud pictures (Unpublished as yet).

6. Ananthakrishnan, R. and Thiruvengadathan, A. 1968: Thermal changes in the troposphere associated with seasonal transition over India. Current Science, Vol. 37, No. 7, pp. 184-186.

7. Ananthakrishnan, R., Mary Selvam, M. and Challappa, R. 1965: Seasonal variation of precipitable water vapour in the atmosphere over India. Ind. Journ. Met. and Geophys., Vol. 16, p. 371.

8. British Met. Office. 1942: Weather in the Indian Ocean Vol. III-Aids to Forecasting. London M.O. 415C(i).

9. Colon, J.A. 1964: On the interaction between the Southwest Monsoon current and the sea surface over the Arabian Sea. Ind. Journ. Met. and Geophys., Vol. 15, p. 183.

10. Dao Shih-Yen and Chen Lung-Shun. 1957: The structure of general circulation over continent of Asia in summer. 75th Anniversary volume of the Journal of the Met. Soc. of Japan, pp. 215-229.

11. Eliot, J. 1900: Hand-book of cyclonic storms in the Bay of Bengal for use of sailors. 2nd Edition Vol. 1.

12. Eliot, J. 1943: Hand-book of cyclonic storms in the Bay of Bengal (Abridged).

13. Flohn, H. 1960: Recent investigations on the mechanism of the "Summer Monsoon of southern and eastern Asia." Symposium on the Monsoons of the World, pp. 75-88.

14. Flohn, H. 1965: Comments on a synoptic climatology of southern Asia. WMO. Tech. Note No. 69, pp. 245-252.

15. India Met. Department. 1942: Winds, weather and currents on the coasts of India and laws of storms. 2nd Edition.

16. Koteswaram, P. 1958: The easterly jet stream in the tropics. Tellus, 10, pp. 43-57.

17. Koteswaram, P. 1960: The Asian Summer Monsoon and the general circulation over the tropics. Symposium on the Monsoons of the World. p. 105.

18. Koteswaram, P. and Bhaskara Rao, N.S. 1963: The structure of the Asian Summer Monsoon. Australian Met. Magazine No. 42, pp. 35-55.

19. Koteswaram, P. and Chakravarthy, K.C. 1950: Distribution of temperature and lapse rate in the upper air over India during different months. Ind. Journ. Met. and Geophys., Vol. 1, No. 2, p. 167.

20. Krishna Rao, P. 1966: A study of the onset of Southwest Monsoon over India during 1962 using TIROS IV radiation data. Ind. Journ. Met. and Geophys., Vol. 17, p. 347.

21. Lockwood, J.G. 1963: Winds at the 200 mb level over the tropics and subtropics during the seasons of monsoon change. Met. Magazine, Vol. 92, No. March 1963, 1088, pp. 75-84.

22. Malurkar, S.L. 1950: Notes on Analysis of Weather of India and neighbourhood. Memoirs of the India Met. Department. Vol. 28, Part IV, pp. 139-170.

23. Mukherjee, T.K. 1962: Precipitable water in the atmosphere over Trivandrum in relation to onset of monsoon. Ind. Journ. Met. and Geophys., Vol. 13, p. 371.

24. Murakami, T. 1958: The sudden change of upper westerlies near the Tibetan Plateau at the beginning of Summer Season. Journal Met. Soc. Japan. Vol. 36, No. 6, pp. 240-247.

25. Nataraja Pillai, M. 1965: Some dynamical aspects of the onset of Southwest Monsoon over India in 1965. Proceedings of the Symposium on the Met. Results of the I.I.O.E., July 1965, p. 413.

26. Pant, P.S. 1964: Onset of Monsoon over India. Ind. Journ. Met. and Geophys., Vol. 15, p. 375.

27. Pant, P.S. and Vernekar, A.D. 1961: A study of the onset of monsoon over India. Proceedings of I.G.Y. Symposium, Vol. 2, p. 20.

28. Pisharoty, P.R. and Desai, B.N. 1956: Western Disturbances and Indian Weather. Ind. Journ. Met. and Geophys., Vol. 7, p. 333.

29. Rai Sircar, N.C. and Patil, C.D. 1961: Horizontal distribution of temperature over India in May during years of early, normal and late Southwest Monsoon. Ind. Journ. Met. and Geophys., Vol.12, p. 377.

30. Rai Sircar, N.C. and Patil, C.D. 1962: A study of high level wind tendency during pre-monsoon months in relation to the time of onset of Southwest Monsoon in India. Ind. Journ. Met. and Geophys., Vol. 13, p. 468.

31. Ramdas, L.A., Jagannathan, P. and Gopal Rao, S. 1954: Prediction of the date of establishment of Southwest Monsoon along the west coast of India. Ind. Journ. Met. and Geophys., Vol. 5, p. 305.

32. Raman, P.K. and Krishnan, A. 1960: Runs of dry and wet spells during Southwest Monsoon and onset of monsoon along west coast of India. Ind. Journ. Met. and Geophys., Vol. 11, p. 105.

33. Raman, C.R.V. 1964: Monsoon definitions. Ind. Journ. Met. and Geophys., Vol. 15, p. 235.

34. Ramamurti, K.K. 1967: High level wind tendency during premonsoon months in relation to the onset of Southwest Monsoon. Ind. Met. Department Scientific Report No. 33.

35. Ramamurthi, K.M. and Keshavmurthy, R.N. 1964: Synoptic oscillations of Arabian Sea anticyclones in the transition season, Ind. Journ. Met. and Geophys., Vol. 15, p. 227.

36. Ramamurthi, K.M. and Jambunathan, R. 1965: On the onset of the Southwest Monsoon rains along extreme Southwest coast of peninsular India. Proceedings of the Symposium on Mot. Results of the I.I.O.E., July 1965, p. 374.

37. Remamurthi, K.M. and Jambunathan, R, 1967: Use of satellite cloud pictures in the study of the Indian Summer Monsoon. Presented at the Indian Ocean Symposium, New Delhi.

38. Ramaswamy, C. 1965: On synoptic methods of forecasting the vagaries of the Southwest Monsoon over India and neighbouring countries. Proceedings of the Symposium on Meteorological Results of I.I.O.E. p. 317.

39. Rangarajan, S. 1963: "Thermal effects of the Tibetan Plateau during the Asian Monsoon Season". Australian Met. Magazine No. 42, p. 24-34.

40. Rao, K.M. 1960: Thermodynamical instability of the upper atmosphere over India during the Southwest Monsoon 'Monsoons of the World', India Met. Department.

41. Riehl, H. 1954: The Indian Summer Monsoon. Tropical Meteorology, p. 256.

42. Roy, A.K. 19461 Air masses in India. Ind. Met. Department Tech. Note No. 16.

43. Simpson, G.C. 1921: The Southwest Monsoon. Q.J.R. Met. Soc. Vol. 47, pp. 151-172.

44. Sutcliffe, R.C. and Bannon, J.K. 1954: Seasonal changes in upper-air conditions in the Mediterranean-Middle East Area. Sc. Proceedings Int. Assoc. Met. IUGG, Rome, pp. 322-334.

45. Thiruvengadathan, A. 1966: Changes in the upper winds over Trivandrum associated with the onset of the monsoon. Presented at the 5th Forecasting Officers Conference, at Poona.

46. Yeh, T.C., Dao, S.Y. and Li, M.T. 1959: The abrupt change of circulating over the northern hemisphere during June and October. The Atmosphei and the Sea in Motion, pp. 249-267.

47. Yin, M.T. 1949: A synoptic-aerologic study of the onset of the Summer Monsoon over India and Burma. J, Met. 6, pp. 393-400.

48. Staff members. Academic, Sinice, Peking. 1957: On the General circulation over eastern Asia(1). Tellus, No. 9 p. 432.

APPENDIX

Extracts from departmental publications describing synoptic features associated with the onset of Southwest Monsoon (1901-1968)

Year	Month Date	* Report	Extract
1901			Onset: ** 7 June/ 5 June
	June	MWR	At the beginning of the month a strong advance of humid monsoon winds was in progress in the extreme southwest of the Arabian Sea. These winds continued to march eastwards during the next 3 days and by the morning of the 5th were established over the whole of the south of the sea as far north as Lat 9° or 10°N. Weather was very squally in front of the advancing current and, as frequently happens a small cyclonic whirl was generated in the area of the disturbed squally weather on the 6th and 7th. The whirl intensified slowly and drifting northwards parallel to the coast, broke up during the 11th off the coast of Kathiawar. With its disintegration the winds, which had been cyclonic in direction in the east of the sea, during the period from the 7th to 11th, returned to their normal monsoon conditions so that on the morning of 12th, ordinary monsoon winds of force 3 to 7 prevailed generally over the Arabian Sea.
	June 5	IDWR	A cyclonic storm is apparently forming in the southeast of the Arabian Sea probably accompanying an advance of the monsoon current.....Conditions are also suspicious in the south and centre of the Bay where the barometer has fallen slightly to briskly.
	7	IDWR	The cyclonic storm in the Arabian Sea has intensified and is apparently this morning opposite the south Konkan coast but at a considerable distance from the coast. The depression in the Bay has apparently advanced northwards and is lying off the Arakan coast.
1902			Onset: 6 June/ 4 June
	June	MWR	At the opening of the month an advance of humid monsoon winds was in progress in extreme southwest of the Arabian Sea. These winds continued to march northeastwards during the succeeding 5 days and by the morning of the 7th were established over the whole of the centre and east of Arabian Sea. There was as is frequently the case a marked tendency to the formation of a depression in front of the advancing current on the 8th and 9th. It developed during the next 2 days and on the morning of the 12th a storm of moderate intensity was shown lying to the west of Kathiawar.
1902	June 6	IDWR	Areas of low pressure probably exist in both the Arabian Sea and the Bay, and gradients are unusually steep in the south and the east of the Peninsula and over south of the Bay.
1903			Onset: 12 June/ 5 June
	June	MWR	On the morning of the 11th the weather became unsettled over Malabar and Ceylon where rain was falling, the wind increasing and the sea raising. On the following morning (the 12th) a slight cyclonic storm was shown off the north Malabar coast and the monsoon had broken at Colombo and in Travancore where heavy rain had fallen. During the next 4-days from 13th to 16th this storm in the Arabian Sea formed the principal feature in the weather conditions.
	June 5	IDWR	The most important change of pressure may perhaps be the brisk decrease in Malabar and west Ceylon; for together with the southeasterly wind at Colombo it may show that weather is disturbed inthe south Arabian Sea.
	11		The chief feature of interest continues to be the abnormal pressure conditions on the west coast, The barometer has again fallen and pressure now is in considerable to large defect in Malabar. There has, however, been no change of importance in the winds on the west coast which continued to be light and unsteady.
	12		The monsoon has broken at Colombo and in south Malabar. It is probably that the advance of monsoon, as is often the case is accompanied with an area of low pressure and disturbed and squally weather which is travelling northwards along the west coast.
1904			Onset: 2 June/ 7 June
	June 2	IDWR	The winds have drawn into cyclonic directions on the Malabar coast.....There are hence some indications of the development of a depression over the southeast of the Arabian Sea.
	7		Small and very shallow depressions apparently exist one over the north of the Bay, a second in the neighbourhood of Allahabad and a 3rd over the south of the central provinces
	8		The southeasterly winds on the Bombay coast probably accompanying slightly disturbed pressure conditions in the east of the Arabian Sea make it probable that the rainfall of next 24 hours will be confined chiefly to the west coast districts.

* MWR - Monthly Weather Report. IDWR - Indian Daily Weather Report.
ARS - Annual Weather Summary. IWR - India Weather Review,
IJMG - Indian Journal of Meteorology and Geophysics.

** First date is the onset of the monsoon given in departmental weather Report. second figure is the date of onset as per FMO, Rep. No. IV - 18·1.

Year	Date	Report	Extract
1906			Onset: 13 June/ 14 June
	June 13	IDMR	The monsoon appears to be setting in on the west coast; the moderately heavy rainfall on the Konkan coast combined with the shifting of winds to easterly and southeasterly directions suggests the existance of an area of low pressure such as usually forms in advance of the monsoon.
1907			Onset: 8 June/ 1 June
	June	MWR	At the end of May an area of low pressure appeared over the southeast of the Arabian Sea and moved northward establishing monsoon conditions along the west coast. A second and much stronger advance of the Arabian Sea monsoon began on the 10th (June) and was preceded by an area of low pressure which travelled northwards. The advance was characterised by the very high seas, strong winds at some distance from the coast and heavy rainfall on the west coast of the Peninsula.
	May 31	IDMR	Conditions are still unsettled on the Malabar coast.
	June 1	IDMR	In the southeast of the Peninsula, weather is still unsettled.
1908			Onset: 11 June/ 7 June
		IMR	As usually happens an area of relatively low pressure moved northwards in front of the advance of the Arabian Sea monsoon and reached the northeast of the Arabian Sea on the 13th (June). By the 15th it had developed into a shallow depression ..... A second advance of the Arabian Sea monsoon began on the 27th (June) and as before it was preceded by an area of relatively low pressure which at the end of the month was still at a considerable distance from the Kathiawar coast. The Arabian Sea monsoon arrived on the Malabar coast on the 11th June about a week later than usual and advanced rapidly northward along the west coast being preceded by an area of relatively low pressure.
	June 8	IDMR	The winds at the Bay Islands and on the Burma coast have changed to southeasterly and indicate the existence of an area of low pressure in the south of the Bay. Conditions are also changing on the Malabar coast.
	11		The monsoon is preceded by an area of relatively low pressure (over Malabar) which is moving northwards in front of it.
1909			Onset: 2 June/ 2 June
	June	MWR	The advance of the monsoon over the Indian Seas resulted only in the production of a feeble depression from 4th to 10th June. The trough of low pressure which usually constitutes an important feature of the pressure distribution of the summer season over Northern India was on the first 3 days of June prolonged further east than usual into Orissa and the adjacent portion of Bay and it was here a depression was generated by the advancing monsoon current during the 24 hrs succeeding 8 hrs of the 4th. The disturbance extended westwards on 5th and on the following morning covered the large area comprising Orissa the southern half of Chota-Nagpur and the east of Central Province..... The advance of the monsoon over the Arabian Sea although not associated with the regular disturbance was marked by winds of unusual violence which inflicted much damage on shipping at the north Malabar coast.
	June 2	IDMR	The disturbed conditions in the Bay are less marked this morning.
			Onset: 2 June/ 4 June
	June	MWR	Owing to the great unsteadiness of the monsoon action over the Arabian Sea low pressures prevailed during a large part of the month along the west coast of the Peninsula but according to the Marine information received upto the present at no time did they result in a definite depression or storm.
	June 2	IDMR	Weather is now probably equally off the shore (Malabar coast)
	4		The area of squally weather off the west coast has concentrated to the west of Kathiawar and cyclonic conditions prevail there.
	11		Onset: 6 June/ 25 June
		IMR	Cyclonic storm (22nd to 27th May). A cyclonic storm apparently formed near the Laccadives on the 22nd. It developed during the next three days.... It disappeared before the morning of 27th.
	May	MWR	During the 4th week (of May) a storm developed in the neighbourhood of Laccadive Islands. It disappeared before the end of the week.
	June		In the month under review a preliminary advance of the monsoon winds over the centre and west of the Arabian Sea occurred during the first few days and an area of low pressure which developed off the west coast of the Peninsula caused a temporary inflow of winds of the monsoon type into India between the 6th and 10th. There was a strong tendency towards the formation of a storm over the southwest of the Arabian Sea during this period, but simultaneously a depression was developing at the head of the B...

Year	Date	Report	Extract
1911	May 25	IDMR	There are slight indications that conditions are disturbed over the Arabian Sea at a considerable distance from the west coast.
	June 5		No further information is available regarding the adverse conditions at sea, already reported, which have been associated with the recent preliminary advance of monsoon winds over the centre and west of the Arabian Sea.
1912			Onset: 8 June/ 5 June
	June	WMR	The Bay was entirely free from disturbance. In the Arabian Sea, the advance of the monsoon was as usual associated with an area of deficient pressure; this first showed itself off Goa on the 11th and during the next 7 days travelled very slowly up the coast to the neighbourhood of Veraval. There is no evidence of its having developed into a regular cyclonic storm.
	June 5	IDMR	Cloud is thickening and an advance of monsoon is now affecting the southern half of the west coast. In the circumstances the usual area of low pressure at sea has come into evidence today ..... In the Bay, yesterday's unsettled conditions have not developed.
1913			Onset: 2 June/ 25 May
	May	WMR	An area of deficient pressure such as accompanies the advance of the monsoon in the Arabian Sea appeared in the extreme south on the 24th, but although a marked increase in rainfall took place on the 29th in the Malabar coast districts, heavy rainfall characteristic of the first burst of the monsoon did not occur until the 2nd June.
	June	WMR	The advance of the monsoon over the Arabian Sea was as usual associated with an area of deficient pressure which travelled up the west coast of the Peninsula without concentrating into a storm, and passed on the 9th into Gujarat where some remarkably heavy downpours of rain occurred round Palitana on the 11th. Over the Bay also the advance of the monsoon gave rise to a depression. This first showed itself on the 12th over the Sand Heads.
	May 24	IDMR	The conditions indicate that the monsoon is entering the southeast of Arabian Sea.
	June 2		The only change of importance is the conditions on the west coast has been an extension northwards of the area affected by the disturbance. The tendency to the formation of a storm over the Bay is maintained.
1914			Onset: 4 June/ 29 May
	May 29	IDMR	Weather is somewhat disturbed over the north of the Bay.
	June 4		The storm in the Bay has crossed the Arakan coast.
1915			Onset: 15 June/ 15 June
	June	WMR	As usually happens a belt of deficient pressure travelled up the Indian Seas in front of the advancing monsoon current. In the Arabian Sea, the low pressure conditions never attained any great intensity and their chief effect was to delay the extension inland of the monsoon .....
	June 15	IDMR	On the Malabar coast the sea is rough, the sky is overcast and the pressure is locally low, indicating that the monsoon is setting in on the coast.
1916			Onset: 2 June/ 22 May
	May	WMR	In the Bay a temporary advance of monsoon winds occurred at the beginning of the month and gave rise to a cyclonic storm. In the Arabian Sea also weather was disturbed during the fourth week owing to the formation of a storm in front of the permanent advance of the monsoon.
	May 22	IDMR	The indications of disturbed weather in the south of the Arabian Sea are more marked and a storm may be forming there.
	June 2		An advance probably temporary is also occurring over the Bay where a storm may be forming.
1917			Onset: 31 May/ 29 May
	May	WMR	Cyclonic storm of the last week of May in the Arabian Sea. This storm was encountered by the SS Port Sea on 25th/26th May in the neighbourhood of Kuria Muria islands, but no information is available regarding its origin, character or movement.
	June	WMR	The advance of the monsoon in the east of the Arabian Sea was as usual associated with a wave of low pressure, but the low pressure conditions failed to concentrate into a definite depression.
	May 29	IDMR	The depression off Cuttack exists but is feeble.
1918			Onset: 11 May/ 11 May
	May 10	IDMR	Conditions remained unsettled in the south of the Arabian Sea and Bay of Bengal.
	11		Weather is probably rough in the southern half of the [illegible]

Year	Date	Report	Extract
1919			Onset: 3 June/ 29 May
	May	MMR	On the morning of the 29th, a depression appeared off the Laccadives in front of the advancing monsoon and developed into a cyclone probably on the 30th with centre near Lat 13°N Long 67°E.
	June 3	IDWR	A storm is forming in the centre of the Bay.
1920			Onset: 3 June/ 4 June
		IMR	The monsoon appeared on the Malabar coast on the 2nd June which is about the usual time and advanced at the normal rate upto the Konkan coast, but it was prevented from extending into the interior of the Peninsula by the formation on the 6th of the severe storm off the Kanara coast in the Arabian Sea.
	June	MMR	The monsoon arrived on the Malabar coast on the 2nd. In the area of squally weather over the Arabian Sea, that usually precedes it a severe storm developed during the next few days (6th onwards).
1921			Onset: 2 June/ 1 June Nil
1922			Onset: 31 May/ 1 June
	June 1	IDWR	The monsoon is establishing itself in the Peninsula without the usual bursts and in the Bay a disturbance is forming which may extend the monsoon towards the United Provinces.
		AWS	Depression of 1st - 7thJune- [illegible] formed in the north of the Bay on the 1st and 2nd June,.....
1923			Onset: 11 June/ 5 June
	June 6	IDWR	Conditions are suspicious in the north of Bay.
	10		The pressure distribution on the west coast is tending to assume the monsoon type.
1924			Onset: 2 June/ 1 June
	June 1	IDWR	Squally weather persists in the southeast of the Arabian Sea.
	3		This advance is however, not associated with the rough seas and pressure changes characteristic of the appearance of the main monsoon current.

Year	Month Date	Report	Extract
1925			Onset: 27 May/ 17 May
	May	MMR	..... and conditions become slightly unsettled in the east Arabian Sea and thunderstorm increased in the Deccan. On the 27th an advance of monsoon marked by an increase of rainfall in Malabar.
	June	MMR	A wave of low pressure, such as usually precedes an advance of the monsoon in the Arabian Sea, had reached the sea off the Konkan on the 1st, and had by the morning of the next day developed into a depression off the south Kathiawar coast.
	May 16	IDWR	The storm in the Bay is severe but of small diameter Its centre lies this morning off the coast near Masulipatam. Weather is suspicious in the southeast of the Arabian Sea where a depression may be forming.
	May 17	IDWR	The Bay storm crossed the coast yesterday near Masulipatam. The storm has now weakened into a depression which lies this morning over the ghats to the west of Vishakapatnam.
1926			Onset: 6 June/ 6 June
		IMR	A temporary advance of the monsoon occurred in the southeast Arabian Sea in the [illegible] week of May,... Strong winds and somewhat rough [illegible]thes was experienced thereafter but the wind directions in the southeast Arabian Sea as given by Ships' observations and at Minicoy together with the pressure changes do not suggest the existance of any well marked depression.
	June	MMR	A shallow depression such as usually precedes the setting in of the monsoon in the southeast Arabian Sea lay off Malabar on the morning of the 9th and was off the North Konkan on the morning of the 11th.
1927			Onset: 27 May/ 19 May
		IMR	In the first week of April, there was a temporary advance of monsoon winds accompanied by unsettled weather in the south of the Bay. In the beginning of May, weather became unsettled in the neighbourhood of Ceylon owing to a temporary advance of monsoon winds into the south of Bay. A second temporary advance of the monsoon occurred in the 2nd week of month (May) but on this occasion the current was directed to the southeast of the Bay. Rainfall commenced in the Nicobars and in south Tenasserim on the 11th and extended northwards to the Pegu coast next day: at the same time conditions became unsettled in the Andaman Sea. An advance of the monsoon took place in the southeast Arabian Sea on the 30th May and caused widespread rain along the west coast and rough sea in the neighbourhood

Year	Month Date	Report	Extract
1927			of Minicoy during the 30th and 31st (May). A depression formed west of the Laccadives on the morning of 31st .....
	May 16	IDMR	The Bay depression passed inland last night across the Arakan coast and disappeared.
1928			Onset: 3 June/ 1 June
		IMR	Advance of monsoon 4th and 13th to 17th June:- In front of an advance of the monsoon in the east of the Bay weather became disturbed on the 4th in the neighbourhood of Lat 17°N Long 90°E. The permanent advance of the Southwest monsoon occurred in the southeast Arabian Sea on the 3rd June with strong winds and rough seas: heavy rain fell along the Malabar coast on that day. The rough weather extended northwards into the east and central Arabian Sea by the 6th and into the whole Arabian Sea by the 8th..... The monsoon strengthened markedly again between the 14th and 17th when rough weather prevailed practically over the whole Arabian Sea.....
	May	MMR	A depression which formed at the head of the Bay on the 12th caused a temporary advance of the monsoon in the south Bay.
	June 1	IDMR	The unsettled conditions in the neighbourhood of the Andamans have disappeared.
	3		A change is noticeable today in the pressure distribution over the west coast.....conditions are now generally favourable for the appearance of the monsoon.
1929			Onset: 29 May/ 30 May
		IMR	In connection with a temporary advance of the monsoon in the south of the Bay weather became unsettled to the northeast of Ceylon on the 10th May.... developed into a depression in the centre of the Bay near Lat 14°N Long 87°E on the morning of 12th May.
			A region of disturbed weather appeared in the south of the Bay on the 29th May in front of an advance of monsoon.....On the morning of 1st June a wide shallow depression was indicated in the north of the Bay. In the next 24 hrs a well marked depression formed in the region with centre near Lat 17 1/2°N Long 91 1/2°E..... The storm commenced to move in the northnortheasterly direction and the centre passed close to Cox's Bazar and Chittagong in the early hours of the 4th.
		ADMR	Associated with an advance of the monsoon in the Andaman Sea on the 10th a storm formed in the North Bay of Bengal and crossed the coast near Akyab on the afternoon of 11th.
1929	May 29	IDMR	Conditions unsettled in the central Bay of Bengal where a depression is probably forming.
	30		Yesterday's unsettled conditions in the central Bay of Bengal are less marked today.
1930			Onset: 8 June/ 3 June
	June 9	IDMR	Weather is suspicious in the central Arabian Sea.
1931			Onset: 4 June/ 29 May
		IMR	Storm of May 14th to 16th:- The first signs of a temporary advance of the monsoon in the south of the Bay became apparent on the afternoon of 10th May.... first signs of unsettled conditions in central Bay appeared on the morning of 13th.
	May	MMR	In connection with a temporary advance of the monsoon in the Andaman Sea, a storm formed in the Bay in the beginning of the 3rd week (14 May to 16 May).
	June 4	IDMR	An advance of the southwest monsoon is occurring in the Andaman Sea and probably also in the southeast Arabian Sea.
1932			Onset: 2 June/ 15 May
	May	MMR	A temporary advance of the monsoon occurred in the southeast Arabian Sea on the 18th and conditions became unsettled off Malabar. On the 20th the unsettled conditions developed into a depression centred about 150 miles north of Amini Divi.
	May 18	IDMR	Conditions are unsettled in the southwest and central Bay of Bengal.
1933			Onset: 22 May/ 18 May
	May	MMR	Widespread and locally heavy rain on the Malabar coast and the adjacent districts of the Peninsula between the 9th and 12th indicated a temporary incursion of monsoon winds in the southeast Arabian Sea..... The region of disturbed weather which is usually found at the head of the monsoon current, was indicated on the weather map of the 15th off the Kathiawar and the Konkan coasts. By the morning of the 17th a depression had formed with its centre about 100 miles to the west of Bombay.
			Weather became unsettled in centre of the Bay on

Year	Month Date	Report	Extract
1933			a depression centre near Lat 12°N Long 89°E on the morning of the 22nd.
	May 18	IDMR	Yesterday's depression off Bombay developed rapidly into a storm and moved slightly northwestwards till midnight; it weakened thereafter into a depression which crossed coast between Veraval and Bhavnagar and lies over Kathiawar this morning.
	22		Yesterday's unsettled conditions in the Bay of Bengal have developed into a depression which is centred this morning near Lat 12°N Long 89°E.
1934			Onset: 8 June/ 7 June
		IMR	Shallow depression of 11th to 14th June:- An advance of the monsoon occurred in the southeast Arabian Sea in the beginning of June, and the monsoon current appeared in the Malabar on the 8th..... After the 8th conditions became favourable for a depression to form in front of the advancing southwest monsoon current.
1935			Onset: 12 June/ 6 June Nil
1936			Onset: 19 May/ 22 May
	May	MMR	The chief feature of the weather during May 1936 was the setting in of the southwest monsoon which appeared simultaneously in the south Bay of Bengal and in the southeast Arabian Sea on the 19th to 20th May. The current advanced rapidly up the Bay where the depression formed near Lat 15°N Long 86°E on the 22nd May.
	May 22	IDMR	Conditions have become unsettled in the southwest Bay of Bengal.
1937			Onset: 4 June / 7 May Nil
1938			Onset: 26 May/ 27 May
	May	MMR	The southwest monsoon made a preliminary advance into the southeast Arabian Sea west of Ceylon and into the south Bay of Bengal about the 12th. Shortly after conditions became unsettled off the Circars/Orissa coast..... The monsoon advanced on the Malabar coast about the 26th and soon after conditions became unsettled in the east central Arabian Sea where a depression formed
1938	May 26	IDMR	A depression formed over the North Bay and rapid. Intensified into a cyclonic storm which is centred this morning near Barisal.
	27		The cyclonic storm crossed coast yesterday and is centred this morning near Jessore.
	28		A low pressure area has appeared in the east centre Arabian Sea.
1939			Onset: 5 June/ 6 June Nil
1940			Onset: 14 June/ 6 June
	May	MMR	In the beginning of 3rd week the monsoon advanced in the southeast Arabian Sea and the south Bay of Bengal and a depression formed off the Coromandal/Circars coast on the 18th morning.
		IMR	Unsettled conditions of 4 to 6 June in the Arabian Sea:- With the strengthening of the monsoon in the southeast Arabian Sea and its advance towards Malabar conditions became unsettled in the east central Arabian Sea off Konkan/Kanara coasts and a feeble cyclonic circulation was noticed there on the morning of 4th June.
	June 5	IDMR	The western disturbances has induced an advance of the monsoon in the Kanara and the Konkan and conditions are unsettled in the east Arabian Sea off that coast. A trough of low pressure lies this morning in the northeast Bay of Bengal.
1941			Onset: 23 May/23 May
		IMR	....An advance of the southwest monsoon occurred in the south Bay of Bengal on the 20th May. Weather became unsettled in the north Andaman Sea by the morning of 21st and a depression formed there within the next 24 hours. A temporary advance of the southwest monsoon appeared in Ceylon and in Malabar on the 22nd May..... Pressure began to fall on the Malabar coast from the evening of the 22nd and conditions were unsettled off Malabar/ Kanara coasts from the 23rd..... Observations indicated the formation of a depression with its central region near Lat 11°N Long 72°E at 8 hrs of 25th.
	May	MMR	The monsoon advanced into the south Bay of Bengal on the 20th and into the Southeast Arabian Sea on the 22nd. By the morning of the 23rd it had burst along the Malabar coast. This advance of the monsoon was followed by the development of the destructive cyclone

Year	Month Date	Report	Extract
1941	May 22	IDMR	A depression has developed in the Andaman Sea and is centred this morning within one degree of Lat 13°N Long 95°E.
	23		The depression in the North Andaman Sea has probably intensified into a storm and is centred this morning about 100 miles northwest of Diamond Island.
1942			Onset: 10 June/ 17 May NSI
1943			Onset: 29 May/ 1 June
	May	MMR	At the beginning of 2nd week, a temporary advance of the monsoon occurred in the southwest of the Bay and locally heavy rain fell in southwest Ceylon on the 6th. The evening charts of the 9th showed fresh northwesterly to easterly winds at higher levels on the Coromandal coasts and indicated a feeble cyclonic circulation in the southwest of the Bay. A depression appeared in the region by the morning of the 11th and developed in the next 24 hrs. Its central region was about 200 miles east of Nagapattinam on the morning of the 12th and it was then probably a cyclonic storm.
	June	MMR	The depression associated with the Bay monsoon current which had appeared at the head of the Bay on the 31st May crossed the coast on the 1st of June.
	May 30	IDMR	Conditions are also unsettled in the north Bay of Bengal.
	June 1		Yesterday's Bay depression is centred this morning within 50 miles south of Calcutta.
1944			Onset: 3 June/ 30 May
	May	MMR	By the 10th weather became markedly unsettled in the southeast Arabian Sea and neighbourhood and ushered in a temporary advance of the southwest monsoon between the 12th and 15th. Another low pressure wave from the east gave rise to unsettled conditions in the north of the Bay of Bengal on the 29th. There was another temporary advance of the monsoon in the south Bay and in the southeast Arabian Sea in the last two days of the month.
	June	MMR	The approach of a fresh pulse of the monsoon was evident on the 8th and this caused unsettled conditions in the east central Arabian Sea on the 10th. The Arabian Sea monsoon current extended northwards upto Bombayy in the next two days and the depression developed off the Kerala coast by the 13th. Since

Year	Month Date	Report	Extract
1944	May 29	IDMR	Weather is thundery in Comorin.
	30		Conditions continue unsettled in the Northeast Bay of Bengal and neighbourhood where a depression is probably existing.
	June 4		Conditions are likely unsettled in the northeast of the Bay.
1945			Onset: 5 June/ 2 June
	June	MMR	The Arabian Sea monsoon burst on the south Malabar coast on the 5th and a feeble temporary extension upto Bombay took place in the next two days. A fresh pulse of the monsoon caused heavy rain in Malabar on the 7th and gave rise to a shallow depression centred near Lat 15°N Long 70°E at 18 hrs of 9th.
	June 2	IDMR	The weather continues unsettled off Malabar and Comorin. Weather is thundery off the Kanara-Konkan coasts.
	5		Weather is unsettled in Comorin and neighbourhood.
1946			Onset: 29 May/ 30 May
		IMD (Part A)	The first advance of the monsoon over Malabar occured on the 28th May ushered in by a cyclonic storm which moved away westwards; The monsoon reached in strength upto Bombay by the 5th of June with heavy rain in the Konkan on that day.
		(Part C)	The southwest monsoon advanced as a feeble current into southeast Arabian Sea on the 28th May and in association with it weather was thundery off the Kanara coast on the 29th and 30th. On the 31st the southwest monsoon burst with its usual vigour on the Malabar coast ..... A deep depression had formed in the centre 08 hrs 2nd June within half degree of Lat 11 1/2°N Long 71°E.
	May 29	IDMR	Weather is unsettled in the east central Bay.
1947			Onset: 3 June/ 3 June
		IMD	The deep depression had intensified into a cyclonic storm by 14 hrs [14th April] and was centred near lat 13°N Long 71°E.....The cyclone brought about a temporary advance of the monsoon into Malabar, Kanara, the Konkan, Gujarat and Saurashtra.

Year	Month Date	Report	Extract
1947	June 2	IDMR	Weather [illegible] in the southeast Arabian Sea.
	3		A low pressure area that moved northwestwards across the [illegible] of Martaban yesterday night has stimulated [illegible] May current and conditions are apparently unsett[illegible] in the North Bay of Bengal and neighbourhoo[illegible]
1948			Onset: 11 June/ 9 June
		IMR	Severe cyclonic storm in the Arabian Sea from 4th June to 10th June 1948.- Ships in the southwest and west Central Arabian Sea reported moderate winds, overcast skies and rain on the 3rd June 1948 indicating that the southwest monsoon was advancing into the area and that weather was becoming unsettled in front of the advancing monsoon. By the evening of the 4th, a depression had formed with its central region near Lat 18°N Long 63°E. Intensifying into a storm on the same day and moving northwards, it weakened into a depression while crossing coast between Pasni and Karachi by the 8th and lay as a trough of low pressure over Baluchistan on the 9th.
	June	IMR	The monsoon burst in Malabar on the 10th..... With its advance northwards, a depression formed in the east Arabian Sea on the 12th with its centre near Lat 14 1/2°N Long 71 1/2°E. It moved Northeastwards, crossed the coast near Harnal by the next evening and became unimportant by the 14th. It caused an advance of the monsoon into the Konkan and the Bombay Deccan by the 13th and 14th.....
	June 9	IDMR	The cyclonic storm in the Arabian Sea weakened into a depression while crossing the east Mekran coast yesterday evening and lies this morning as a trough of low pressure over Baluchistan.
	11		Associated with the advance of the monsoon, conditions are unsettled in the east Arabian Sea off North Malabar and Kanara coasts where a depression may form. Yesterday's unsettled conditions in west Central Bay of Bengal are less marked and may become unimportant.
49		[illegible]	Onset: 23 May/ 24 May
		IMR	The formation and movement of the depression in the Bay of Bengal between 21 to 25 May was responsible for the advent of the monsoon into the extreme south of the Bay by the 22nd May..... The depression also carried the monsoon into the southeast Arabian Sea and into Malabar where heavy rain was recorded on 23rd morning.
	May 23	IDMR	The Bay of Bengal depression weakened and crossed the coast during night and lies this morning as a shallow low over the Madras Deccan. It may emerge into the Arabian Sea and intensify the trough of low pressure which exists this morning off the Konkan coast.

Year	Month Date	Report	Extract
1949	May 24	IDMR	The shallow low over the Madras Deccan is passing out into the Arabian Sea off Kanara, where a depression may form.
1950			Onset: 27 May/ 28 May
		IMR	Under the influence of the deep depression in the Bay of Bengal from 23 to 30th May 1950, the southwest Monsoon advanced into Travancore-Cochin on 27th and into Malabar/ south Kanara on the 28th.
	May 27	IDMR	The deep depression in the west Central Bay of Bengal is centred at 0300 hrs GMT within one degree of Lat 15 1/2°N Long 85°E.
	28		The depression in the west central Bay of Bengal has weakened into a trough of low pressure off the Circars coast.
1951			Onset: 31 May/ 1 June
		IMR	By the 1st June the monsoon has advanced into the south Bay and was advancing into the east central Bay of Bengal. In association with the above, a region of marked pressure fall extended from the southwest Bay to the central parts of the Bay. This developed into a shallow depression.
	June+ 1	IDMR	A well marked trough of low pressure extends from the north Andaman Sea to off Orissa coast.
	June 2		The unsettled conditions in West Central Bay of Bengal have become more marked and a depression may form off the Circars coast.
1952			Onset: 20 May/21 May
		IMR	Under the influence of the severe cyclonic storm in the Bay of Bengal 20 to 25 May, the southwest monsoon was ushered in Travancore-Cochin on the 20th May about 10 days before the usual date.
	May 20	IDMR	Yesterday's depression the west central Bay of Bengal persists and is centred at 0300 hrs GMT about 300 miles east of Madras. I.T.C.Z. at 5030' runs from Trivandrum to Sandoway
	21		Yesterday's depression in the west central Bay of Bengal rapidly intensified into a cyclonic storm. It is now severe and is centred at 0300 hrs GMT about 120 miles eastnortheast of Madras.
1953			Onset: 7 June/ 7 June
	June	IDMR	[illegible]

Year	Month Date	Report	Extract
1953			Andaman Sea and neighbourhood upto 3000-5000 ft a.s.l. and on 3rd and 4th June.
1954			Onset: 31 May/ 22 May
	May	MMR	In association with a trough of low in the east Arabian Sea off Malabar/Kanara coast between 29th and 30th, local or fairly widespread thunder-showers occurred in south Deccan(Deoh), Hyderabad, Malabar, and south Kanara on the 30th. The Arabian Sea branch of the monsoon advanced into Travancore-Cochin on the 31st as a feeble current.
	May 21	IDWR	Yesterday's disturbance off the Kanara coasts is less marked.
	23		A shallow trough of low pressure exists in the east Arabian Sea off Kanara coast.
	30		The unsettled conditions in the west central Bay have become less marked. The trough of low pressure off Malabar coast is less marked.
	31		Conditions are becoming unsettled in the North Bay of Bengal.
1955			Onset: 29 May/ 11 May
	May	MMR	Conditions became unsettled in the southeast Bay of Bengal on the 14th. Incursion of maritime air started on the same day and on the morning of 17th, a deep depression formed with its centre about 200 miles, to the east of Nagapattinam. The depression was responsible for a temporary advance of SW monsoon into Travancore-Cochin and Malabar/S.Kanara coasts on 19th,
	May 11	IDWR	The unsettled conditions in the west central and adjoining southeast Bay of Bengal have become less marked. A temporary incursion of Equatorial maritime air is taking place in the Maldives area.
	12		A cyclonic circulation extending to 7000' a.s.l. has formed over North Gujarett and neighbourhood.
	28		The trough of low off the Malabar-South Kanara coasts persists and may serve to extend the monsoon into Malabar-South Kanara.
	29		The trough of low pressure off the Malabar - South Kanara coasts has shifted slightly northwards and extends to South Konkan. Conditions are unsettled in the east central Bay of Bengal and neighbourhood.
	30		The trough of low pressure off the Kanara coast is becoming less marked.
	May	IJMG	A trough of low pressure formed off the Kanara - south Konkan coast on the 26th and persisted there
1956			took place over Travancore - Cochin and Malabar south Kanara coasts where it finally established itself by the 29th.
			Onset: 21 May/ 16 May
	May 16	IDWR	The trough of low off the Konkan-South Kanara coast persists but is feeble.
	20		In association with a trough of low pressure off the Malabar- Kanara coasts, a temporary advance of the monsoon is taking place into Travancore, Cochin and South Malabar.
	21		The trough of low pressure off Malabar - Kanara coasts is getting accentuated.
		IJMG	In association with a well marked trough of low pressure extending from Uttar Pradesh to the West Central Bay of Bengal, which developed on the 10th and persisted till the 15th, a temporary advance of the monsoon took place into the south Andaman Sea on the 11th. A trough of low pressure appeared off the Malabar-south Kanara coast on the 14th and persisted there with varying intensity for more than a fortnight. Under its influence, the Arabian Sea branch of the monsoon advanced into Maldives - Comorin area on the 18th, into Travancore-Cochin and Malabar coast on the 21st, into south Kanara on 22nd into north Kanara on the 26th, into south Konkan on the 27th, and into north Konkan on 29th.
1957			Onset: 1 June/ 30 May
	May 31	IDWR	Weather is unsettled in the east Central Bay of Bengal.
	June 1		The unsettled conditions over the east central Bay of Bengal are less marked and a low pressure wave is apparently approaching north coastal Andhra Pradesh.
		IJMG	A well marked trough of low pressure developed in the southeast Arabian Sea off the Malabar coast and adjoining Comorin area on the 18th (May). Under its influence a temporary advance of the southwest monsoon took place into Kerala and neighbourhood on 21st..... .....A shallow depression formed on the 26th, May with centre about 200 Kms west of Karwar..... The southwest monsoon next advanced into Comorin-Maldives area on the 30th then the Bay Branch also advanced into southeast Bay of Bengal and Andaman Sea.
1958			Onset: 14 June/ 14 June
	June	IDWR	The trough of low pressures in the east Arabian Sea

Year	Month Date	Report	Extract
1958		[illegible]	In association with a trough of low pressure that formed in the east Arabian Sea on the 13th(June) the monsoon advanced into Kerala and south coastal Mysore on the 14th..... In association with a low pressure wave which moved westwards across the north Bay the monsoon advanced as a feeble current into Gangetic West Bengal, Chotanagpur and Orissa on the 24th.....
1959			Onset: 31 May/ 30 May
	May	MMR	A depression formed in southeast Arabian Sea on the morning of 19th May.....intensified into a cyclonic storm on 21st.....Under its influence maritime air penetrated into the south Peninsula. Fairly widespread thundershowers occurred in coastal and south interior Mysore, in Kerala and in Arabian Sea Islands during this period.
	June	MMR	A shallow trough of low pressure appeared in the east central Arabian Sea off the south Konkan coast on 4th. Under its influence, the Arabian Sea branch of the southwest monsoon which had advanced into Kerala on the 31st May extended further northwards into north Kerala on the 4th June.
	May 20	IDMR	Yesterday's depression is now deep and is centred at 0300 hrs GMT today within one degree of Lat 12.5°N Long 69.5°E.
	27		.....An upper air trough exists over the southeast Arabian Sea and under its influence conditions are becoming favourable for the advance of the monsoon into the Comorin and Maldives area.
	29		.....The seasonal trough of low pressure extends into the Bay.
	31		.....The Southwest monsoon has advanced into the south Malabar coast. The monsoon is also advancing into the southwest Bay of Bengal. The axis of the seasonal trough at 1.5 Km a.s.l. passes through Sriganganagar, Allahabad and Dacca.
1960			Onset: 14 May/ 14 May
	May	MMR	On the 10th, a depression developed in the southeast Arabian Sea over Laccadives area. It moved in northwesterly direction and intensified into a cyclonic storm on the 14th evening. It became a severe cyclonic storm with a core of hurricane winds, by 17th morning centred near Lat 14.5°N Long 59°E. In association with these developments fairly widespread premonsoon thundershowers with some heavy to very heavy falls occurred in Kerala between 3rd and 7th and in the Arabian Sea Islands on 9th and 10th. Monsoon proper advanced into Kerala on 14th more than a fortnight earlier than usual.
	May 14	IDMR	The deep depression in the Arabian Sea was centred at 0300 hrs GMT within one degree of Lat 14.5°N and Long 64.5°E. A well marked trough of low pressure exists over the southwest and the adjoining southeast Bay of Bengal.
1961			Onset: 18 May/ 19 May
	May	MMR	Another easterly wave entered the Andaman Sea on 12th May crossed the south Peninsula by 16th and gave rise to a trough of low pressure in the southeast Arabian Sea off the Malabar coast on 17th.....It concentrated into a depression and then rapidly into a cyclonic storm centred about 150 Km west-southwest of Honavar on the morning of 23rd.....The Arabian Sea branch of the monsoon advanced into extreme south Kerala on 18th.
	May 18	IDMR	Trough associated with the other easterly wave still persists over the southeast Arabian Sea off the Malabar coast.
	19		The trough in the southeast Arabian Sea is well marked.
1962			Onset: 17 May/ 15 May
	May	MMR	A low pressure area formed in the southwest Bay of Bengal on the 13th, and intensified into a deep depression on the 15th morning with its centre about 200 Kms east of Cuddalore.....It further intensified into a cyclonic storm by the same evening.....It crossed Coromandel coast.....weakened into a deep depression and emerged into the Arabian Sea near Mangalore on the 18th.....Under its influence the southwest monsoon advanced into south Kerala on 17th.....
	May 15	IDMR	The well marked low pressure area in the southwest Bay of Bengal intensified into a depression. It lies at 0300 hrs GMT as a deep depression with its centre within half a degree of Lat 11.5°N Long 82°E.
	17		Yesterday's deep depression in the south Peninsula lies at 0300 hrs GMT today with centre at Palghat. Associated strong cyclonic circulation prevails over south Peninsula and neighbourhood extending to 9 Km a.s.l.
1963			Onset: 31 May/ 5 June
	May 31	IDMR	It is believed that the unsettled conditions over south west Bay now lies as an upper air low above 2.0 Km over extreme south Peninsula and neighbourhood. Another upper air low also lies over the south Andaman Sea between 4.0 and 6.0 Km a.s.l.
	June 5		Yesterday's upper air low over northwest Bay of Bengal and the adjoining areas persists and extends upto 9.0 Km
	May	IDMO	In association with an upper air low which moved [illegible]

Year	Month Date	Report	Extract
1963			the south Peninsula from the southwest Bay of Bengal, the southwest monsoon advanced into extreme south Kerala on 31st.....
1964			Onset: 6 June/ 7 June
	June	IJMG	A low pressure area forming over the east central Arabian Sea off the Kanara coast on 6th (June) moved northward and intensified into a severe cyclonic storm.....Under its influence the monsoon rapidly advanced northwards and set in over the entire west coast by 12th.
1965			Onset: 26 May/ 6 June
	May 26	IDMR	Ships observations from Central Bay are absent. It is believed that the well marked low pressure area over the central Bay concentrated into a depression which lay at 0300 hrs GMT today. with centre within a degree of Lat 15°N Long 89°E.
	June 6		The trough of low pressure lies over south Maharashtra and Mysore coasts.
	May	IJMG	Under the influence of a well marked low pressure area over the Central parts of the Bay of Bengal' a depression formed on the 26th morning with centre near Lat 15°N Long 89°E. It intensified into a severe cyclonic storm by the evening of 31st..... Under its influence the southwest monsoon advanced into the extreme southeast Bay of Bengal and south Andaman Sea and extended northwards into the east Central Bay. The Arabian Sea branch of the monsoon also advanced into south Kerala on 26th.
1966			Onset: 1 June/ 3 June
	June 1	IDMR	Yesterday's well marked low pressure area lies over the east central and adjoining north Bay of Bengal.
	3		It is believed that yesterday's well marked low pressure area over the central Bay concentrated into a depression, probably deep, by last evening and was centred at 0300 hrs GMT today about 200 Kms southeast of Vishakapatnam.
	June	IJMG	A depression lying over the west central Bay of Bengal on 2nd moved into the north Peninsula and weakening as a trough of low pressure moved across east central Arabian Sea to northeast Arabian Sea by 13th, Under its influence, the southwest monsoon advanced into south Kerala by the normal date of 1st June.....The Bay branch of the monsoon also advanced into Assam by 6th.....

Year	Month Date	Report	Extract
1967			Onset: 9 June/ 8 June
	June	MWR	A trough of low pressure developed over the central parts of the Arabian Sea by the 10th. It shifted slowly northwards to north Arabian Sea where it became unimportant by the 16th. Under its influence the monsoon advanced as a feeble current along the west coast upto Surat by the 17th.....
	June 8	IDMR	The seasonal low pressure over the northeastern parts of west Pakistan and neighbourhood is well marked.
	9		The seasonal low over the northeastern parts of west Pakistan and neighbourhood continues to be well marked.
1968			Onset: 8 June/ 8 June
	June	MWR	The southwest monsoon which advanced into the Comorin and Maldive areas by the end of May did not extend northwards for the next one week. It set in over Kerala on 8th..... A feeble trough of low pressure developed over the extreme east central Arabian Sea off the Mysore coast on 8th. It persisted there for the next 3 days.....Under its influence the monsoon advanced steadily northwards and covered the Peninsula by the middle of the month.

FIG. I : NORTH-SOUTH VARIATION OF PRESSURE AND PRESSURE GRADIENT ACROSS INDIA DURING APRIL- MAY- JUNE

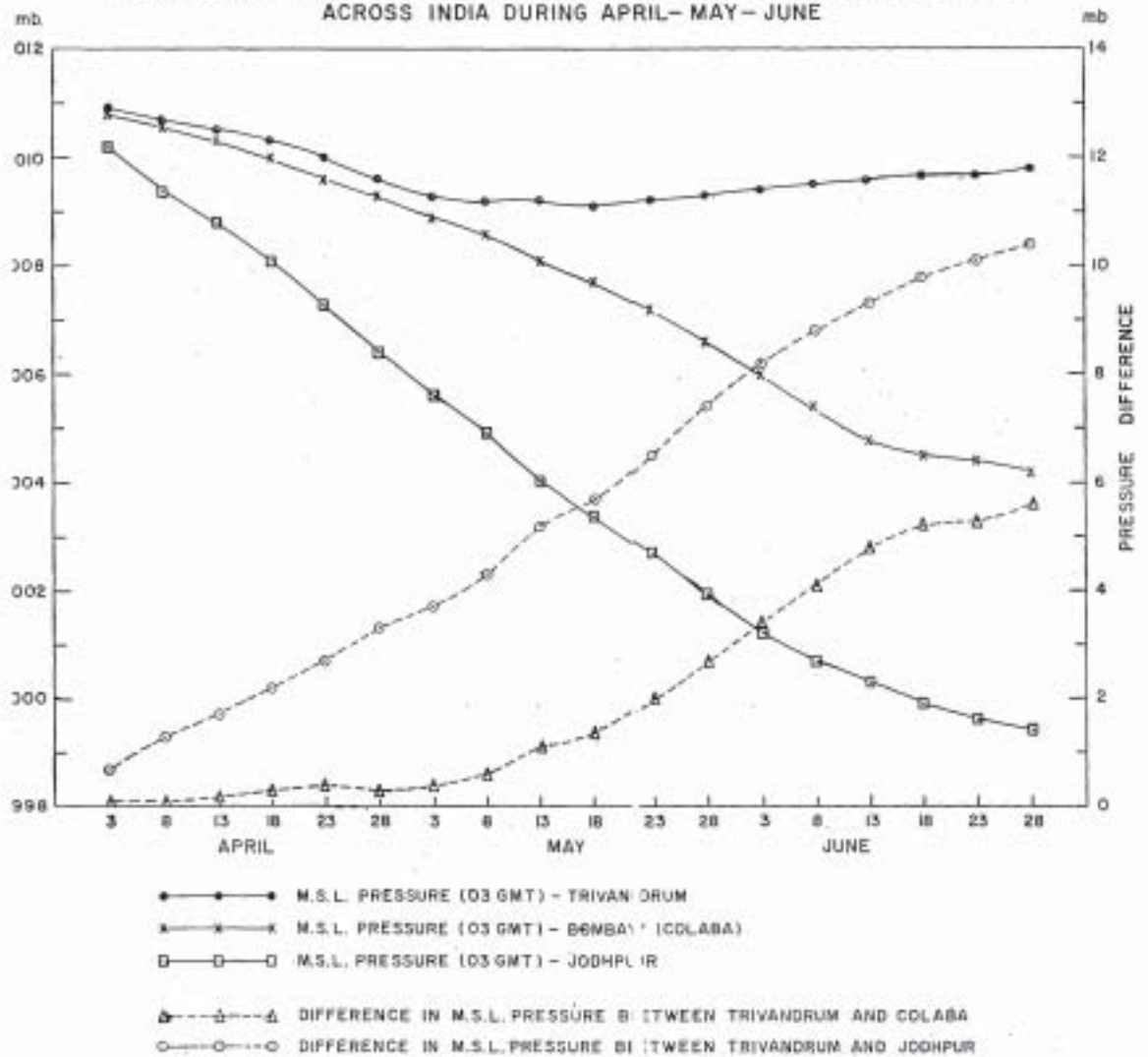
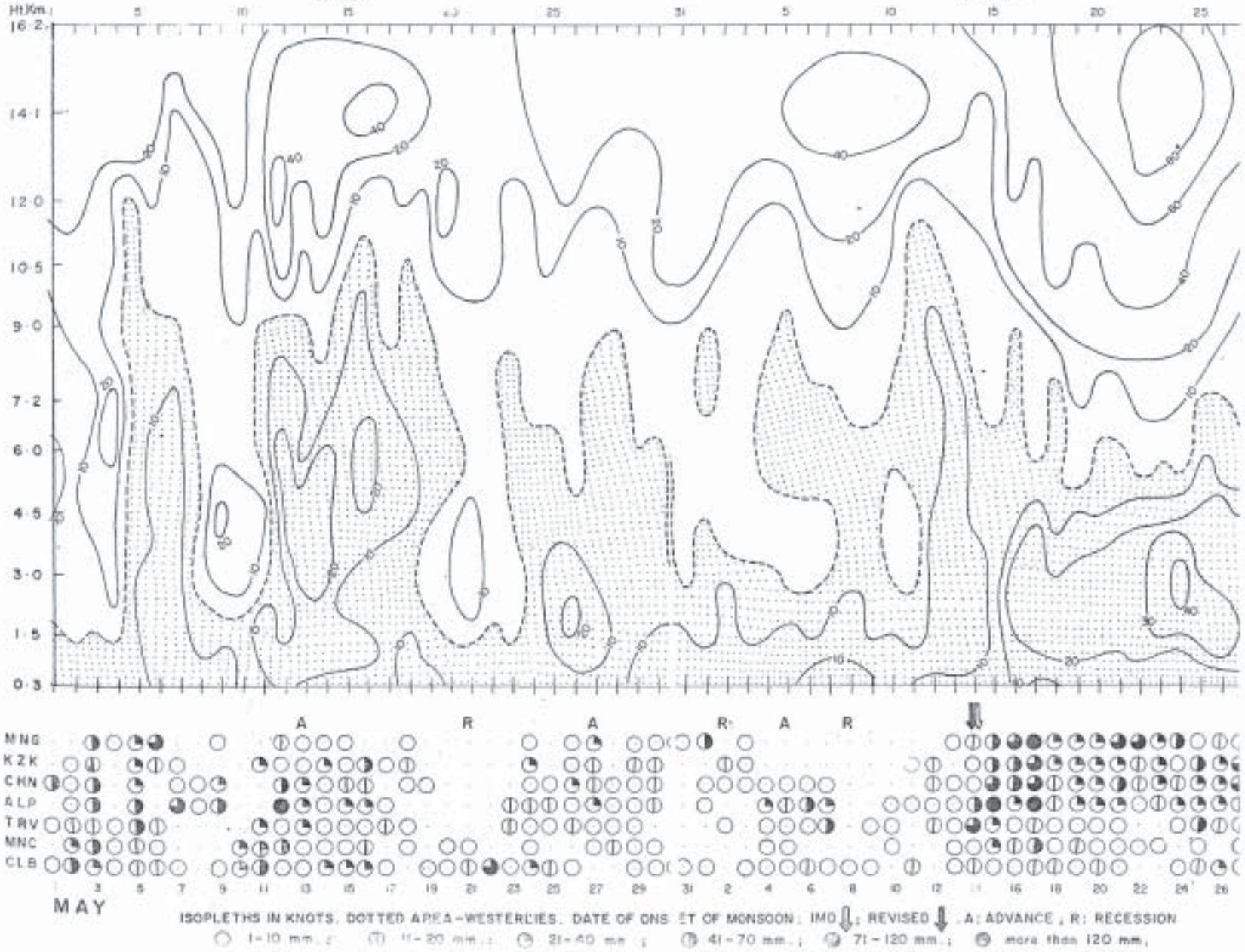
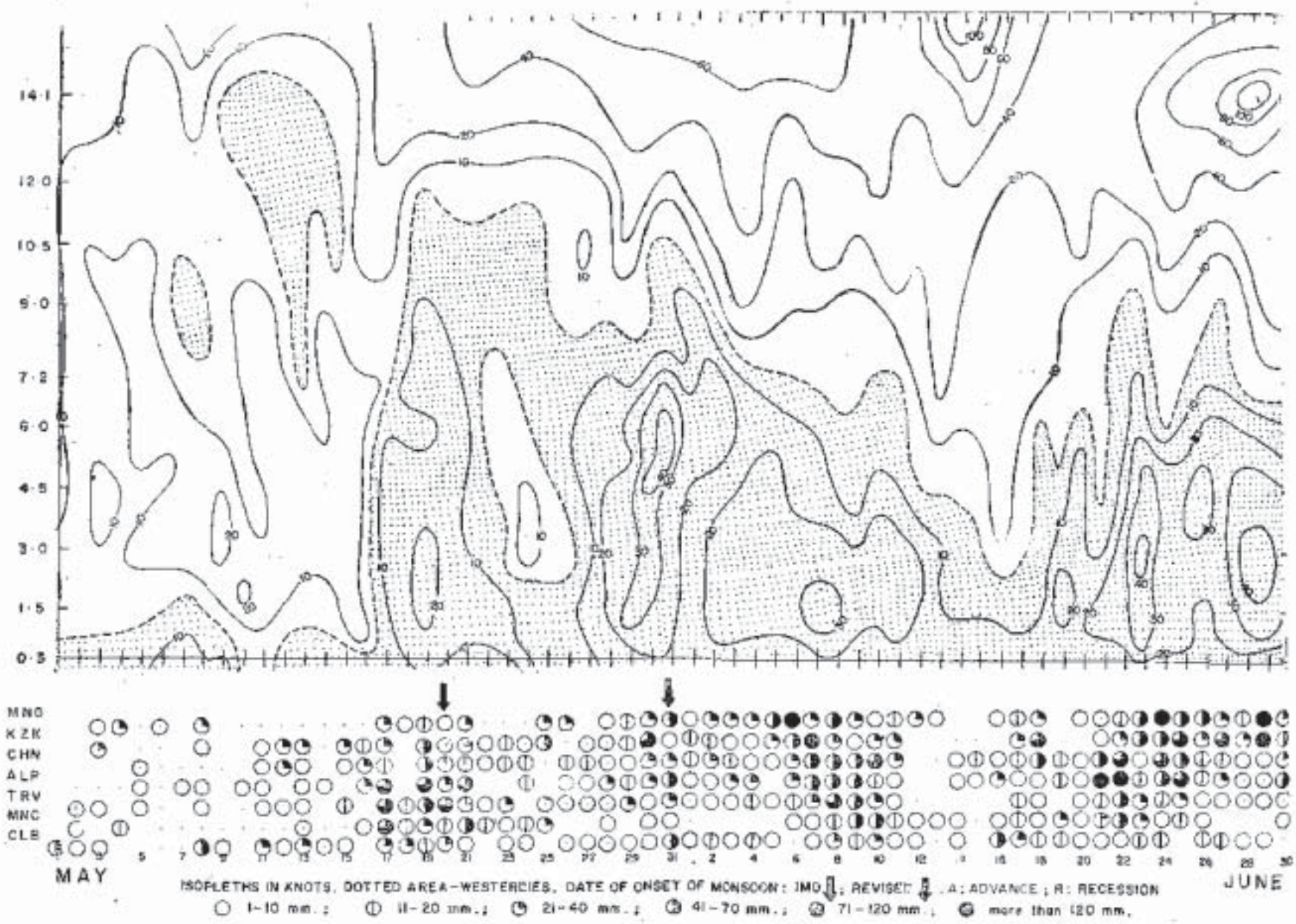
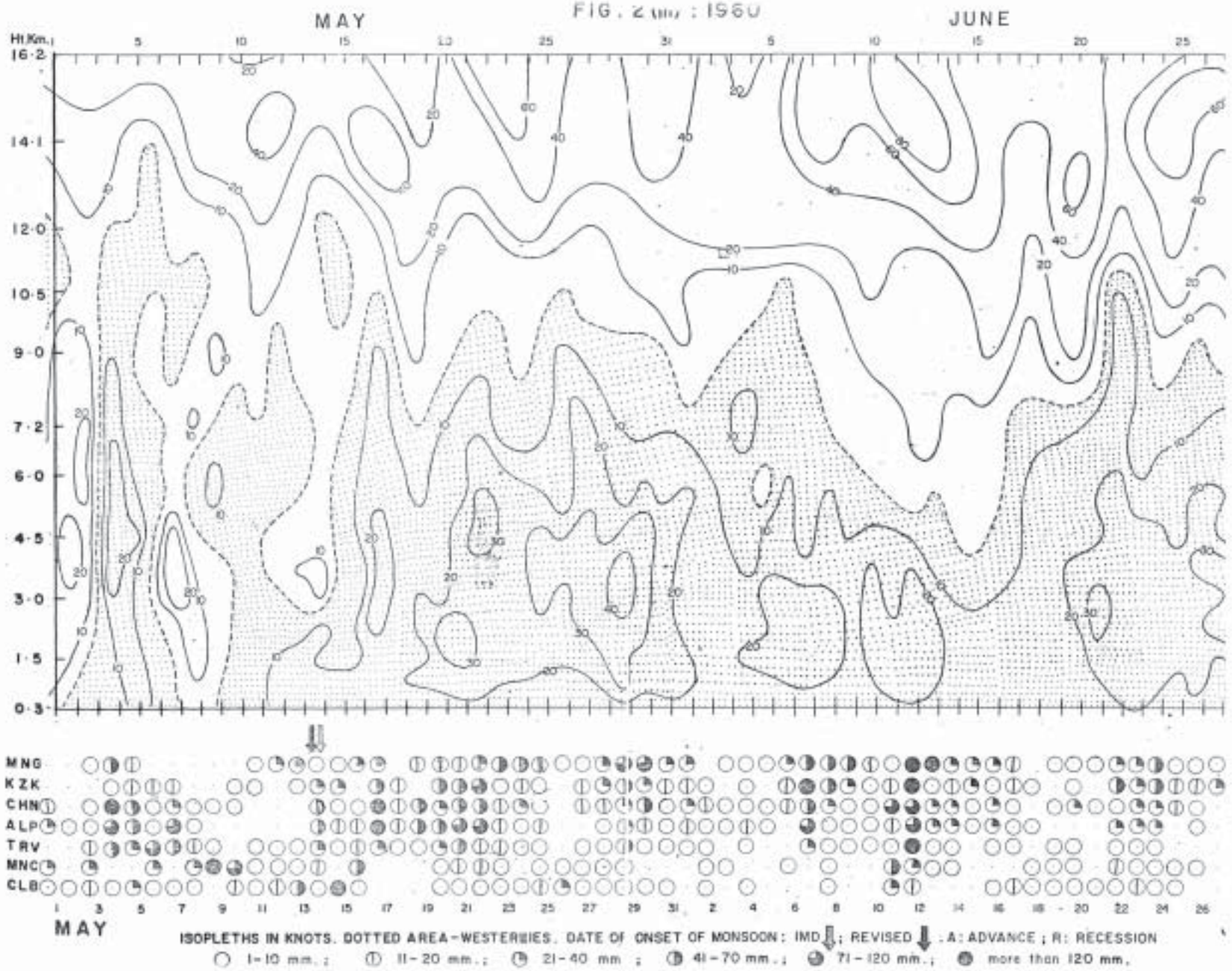


FIG. 2(i) : 1958


MAY
JUNE
Ht.Km.
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
MNG
KZK
CHN
ALP
TRV
MNC
CLB
A
R
A
R
A
R
MAY
ISOPLETHS IN KNOTS. DOTTED AREA-WESTERLIES. DATE OF ONSET OF MONSOON: IMD ⇩; REVISED ⇩. A: ADVANCE, R: RECESSION
1-10 mm.; 11-20 mm.; 21-40 mm.; 41-70 mm.; 71-120 mm.; more than 120 mm.


14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·5
MNG
KZK
CHN
ALP
TRV
MNC
CLB
MAY
JUNE
ISOPLETHS IN KNOTS, DOTTED AREA-WESTERLIES, DATE OF ONSET OF MONSOON: IMD ⇩; REVISED ⇩, A: ADVANCE; R: RECESSION
1-10 mm.; 11-20 mm.; 21-40 mm.; 41-70 mm.; 71-120 mm.; more than 120 mm.


MAY
JUNE
Ht.Km.
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
MNG
KZK
CHN
ALP
TRV
MNC
CLB
MAY
ISOPLETHS IN KNOTS. DOTTED AREA-WESTERLIES. DATE OF ONSET OF MONSOON: IMD; REVISED . A: ADVANCE ; R: RECESSION
1-10 mm.; 11-20 mm.; 21-40 mm ; 41-70 mm.; 71-120 mm.; more than 120 mm.

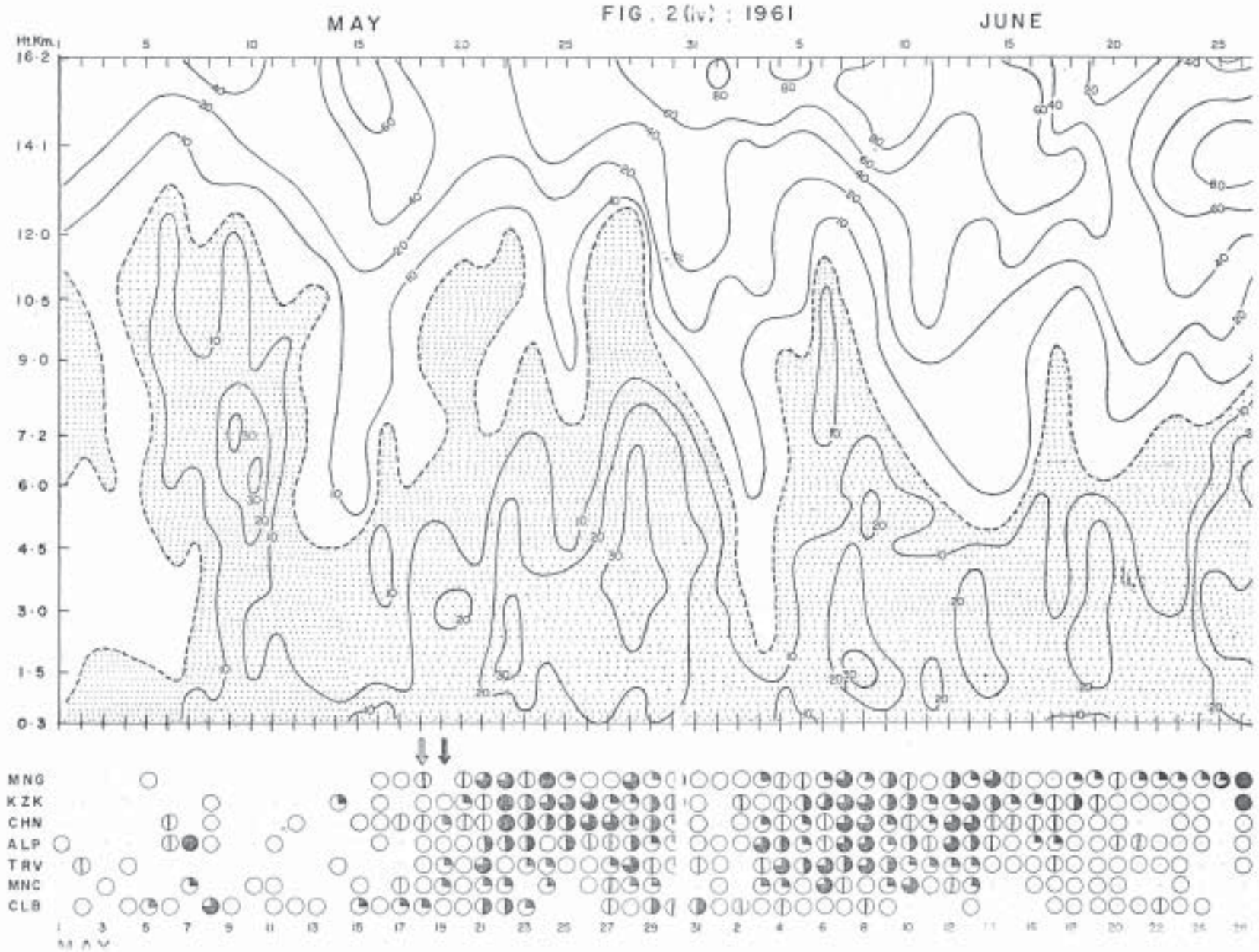
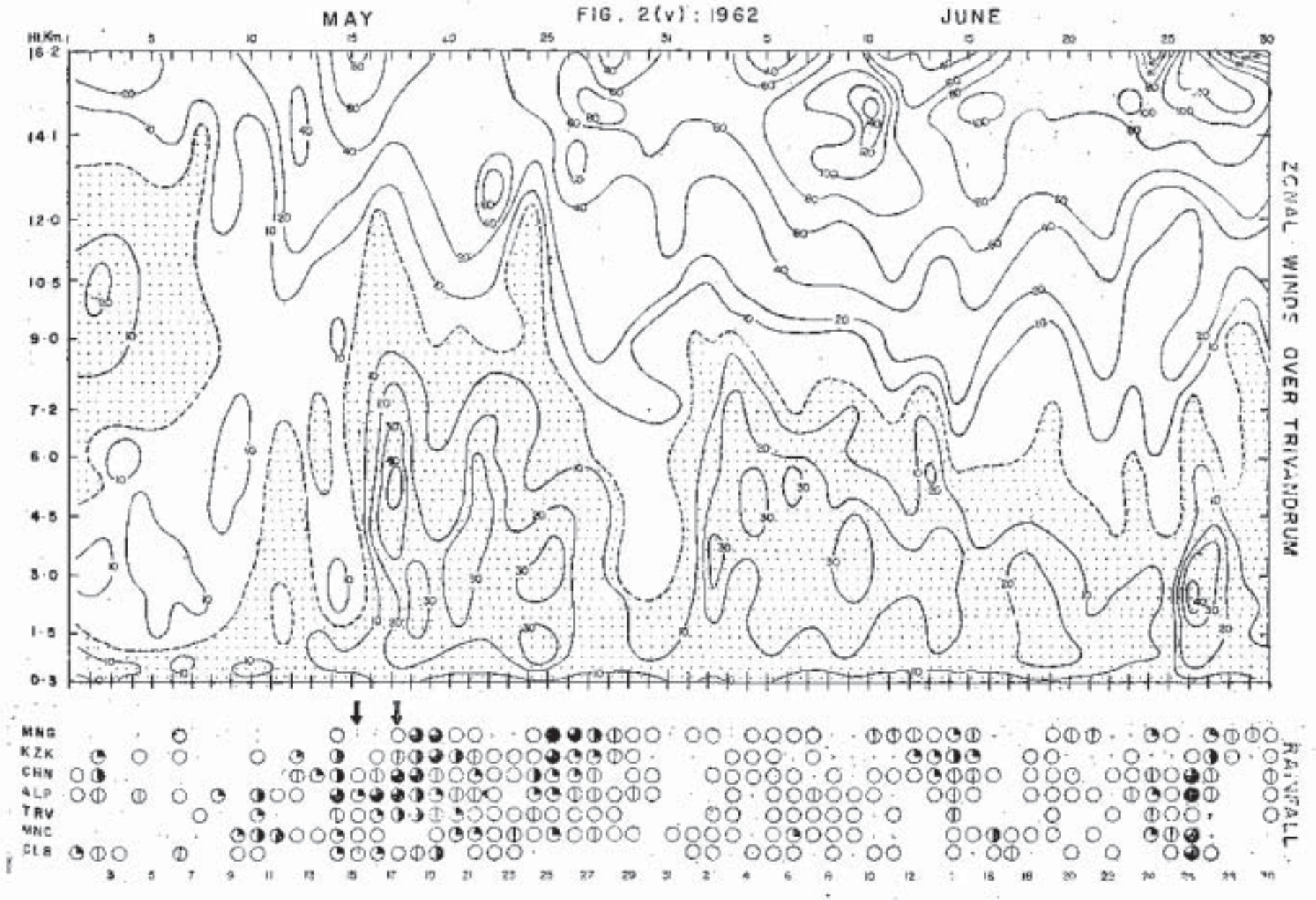


FIG. 2(iv) : 1961
MAY
JUNE
Ht.Km.
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
MNG
KZK
CHN
ALP
TRV
MNC
CLB
MAY


MAY
FIG. 2(v) : 1962
JUNE
ZONAL WINDS OVER TRIVANDRUM
RAINFALL
MNG
KZK
CHN
ALP
TRV
MNC
CLB

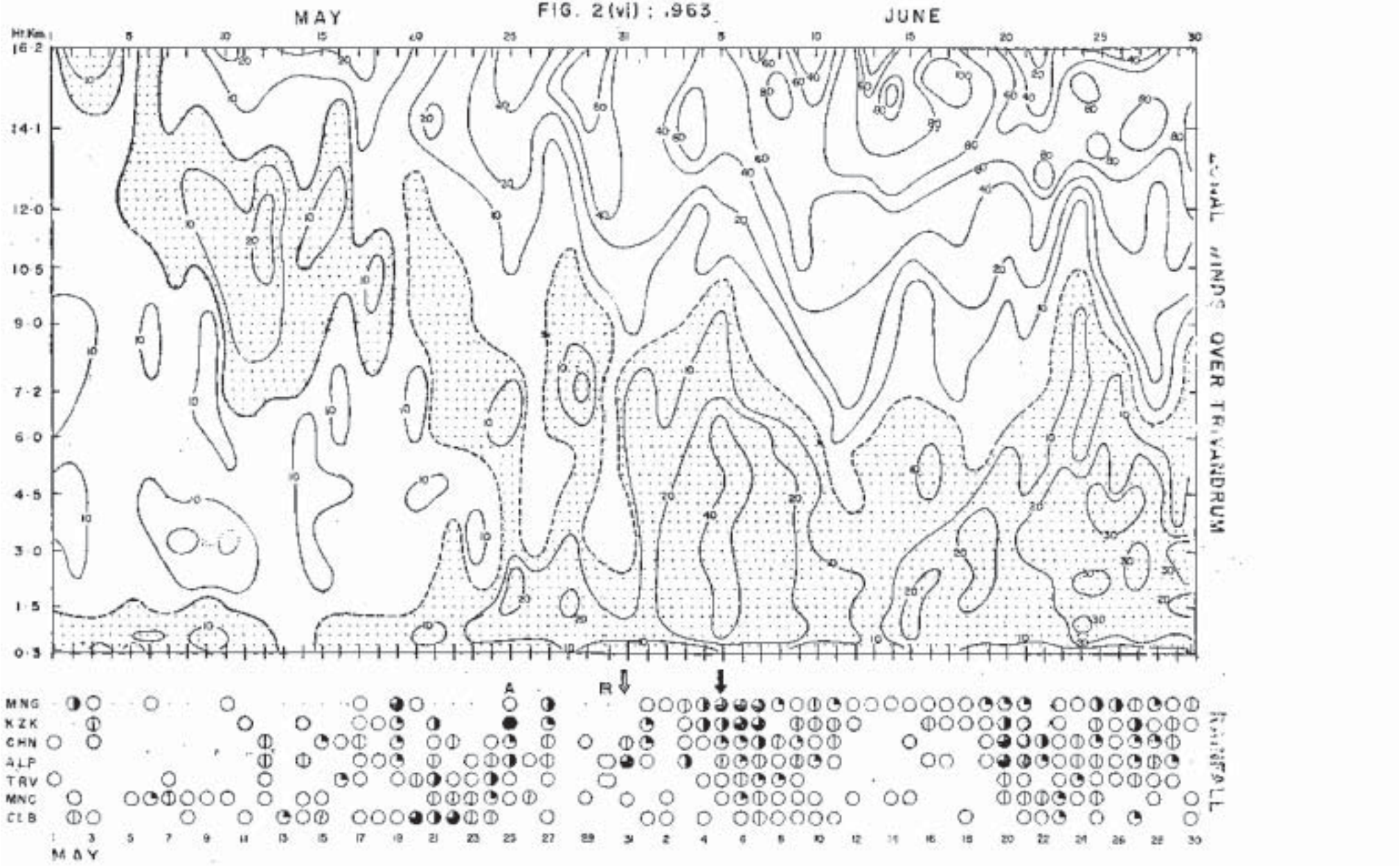


FIG. 2(vi) : 1963
MAY
JUNE
Ht.Km.
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
MNG
KZK
CHN
ALP
TRV
MNC
CLB
A
R
MAY

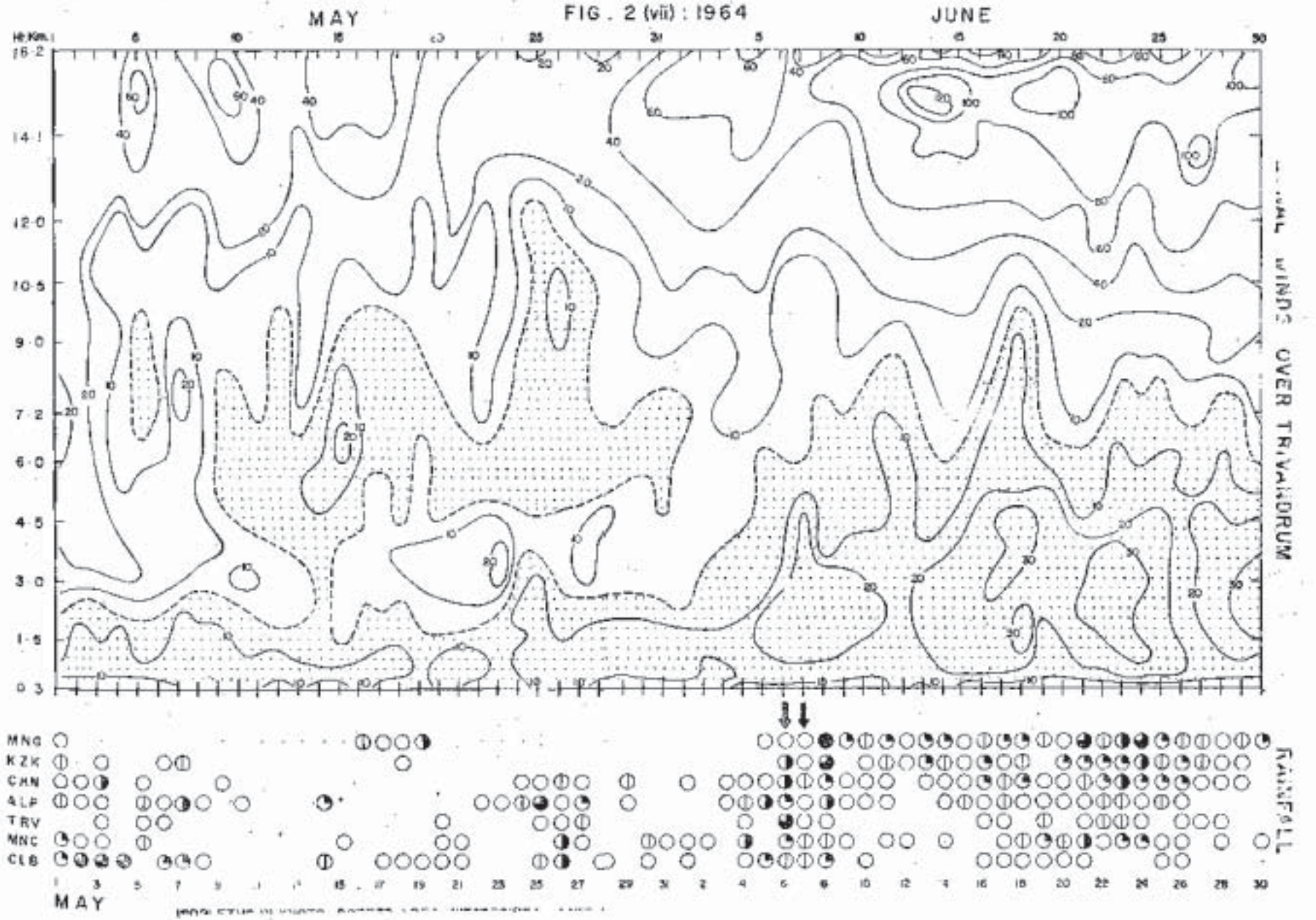


FIG. 2 (vii) : 1964
MAY
JUNE
Ht.Km.
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
MNG
KZK
CHN
ALP
TRV
MNC
CLB
RAINFALL
MAY

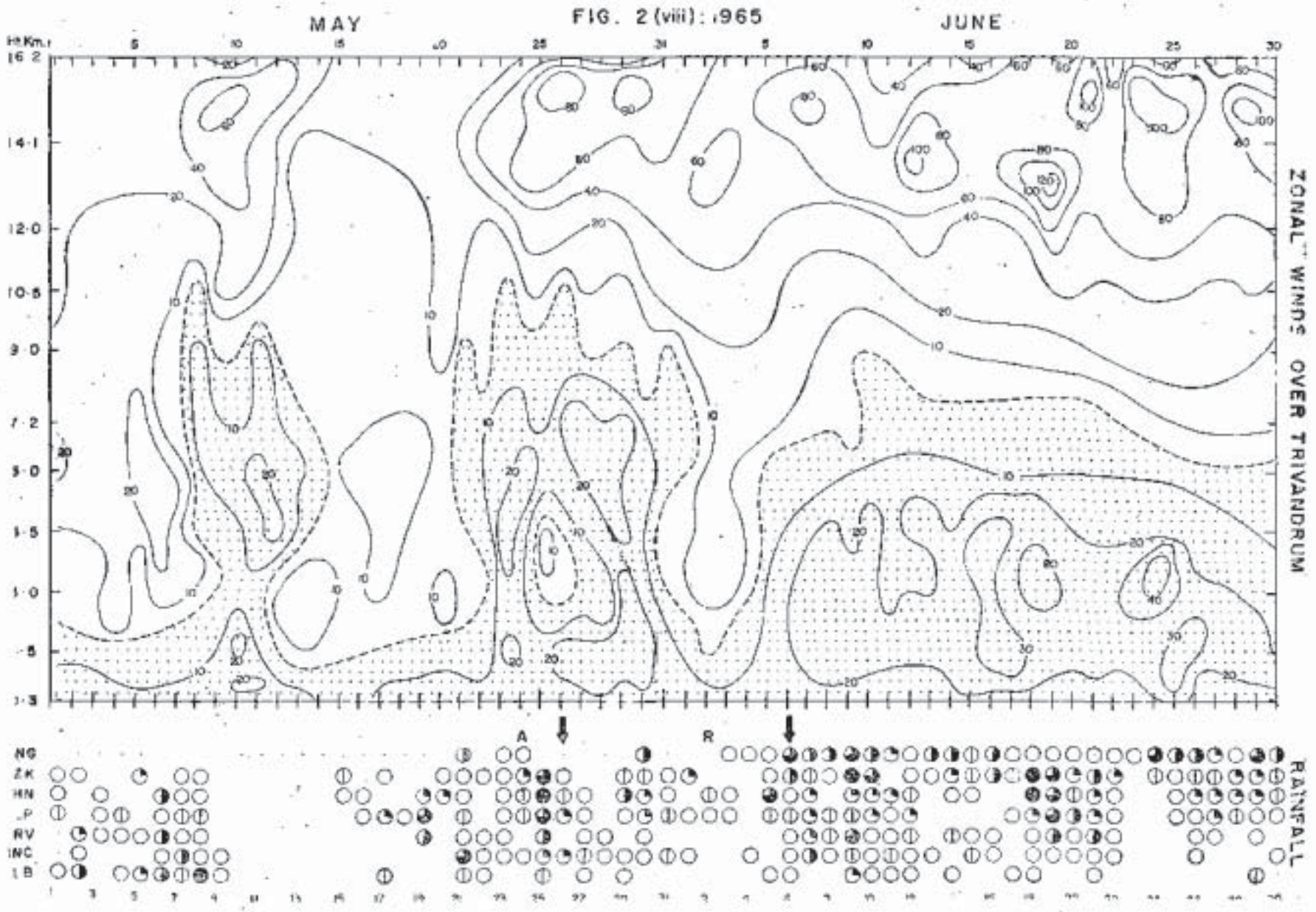
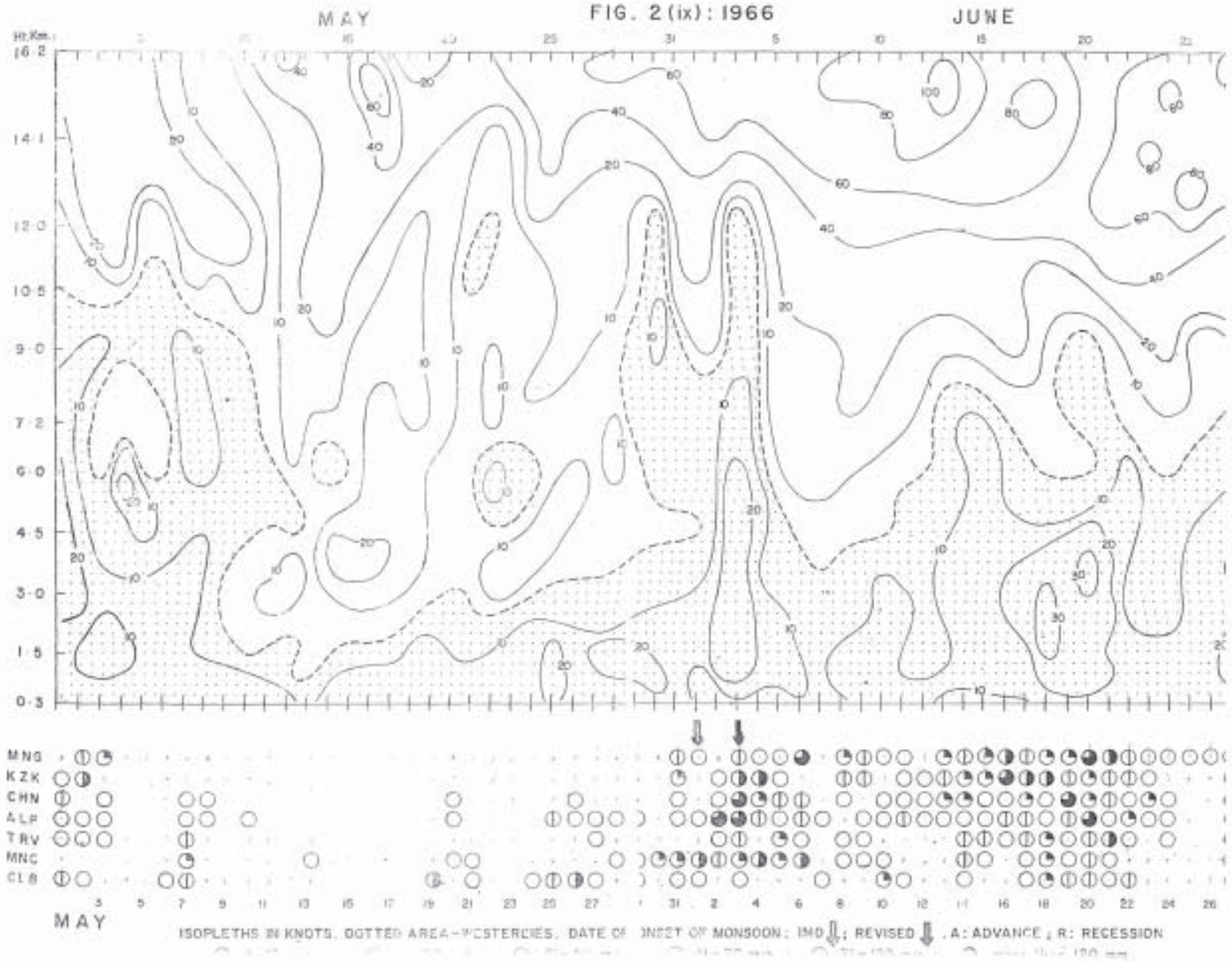
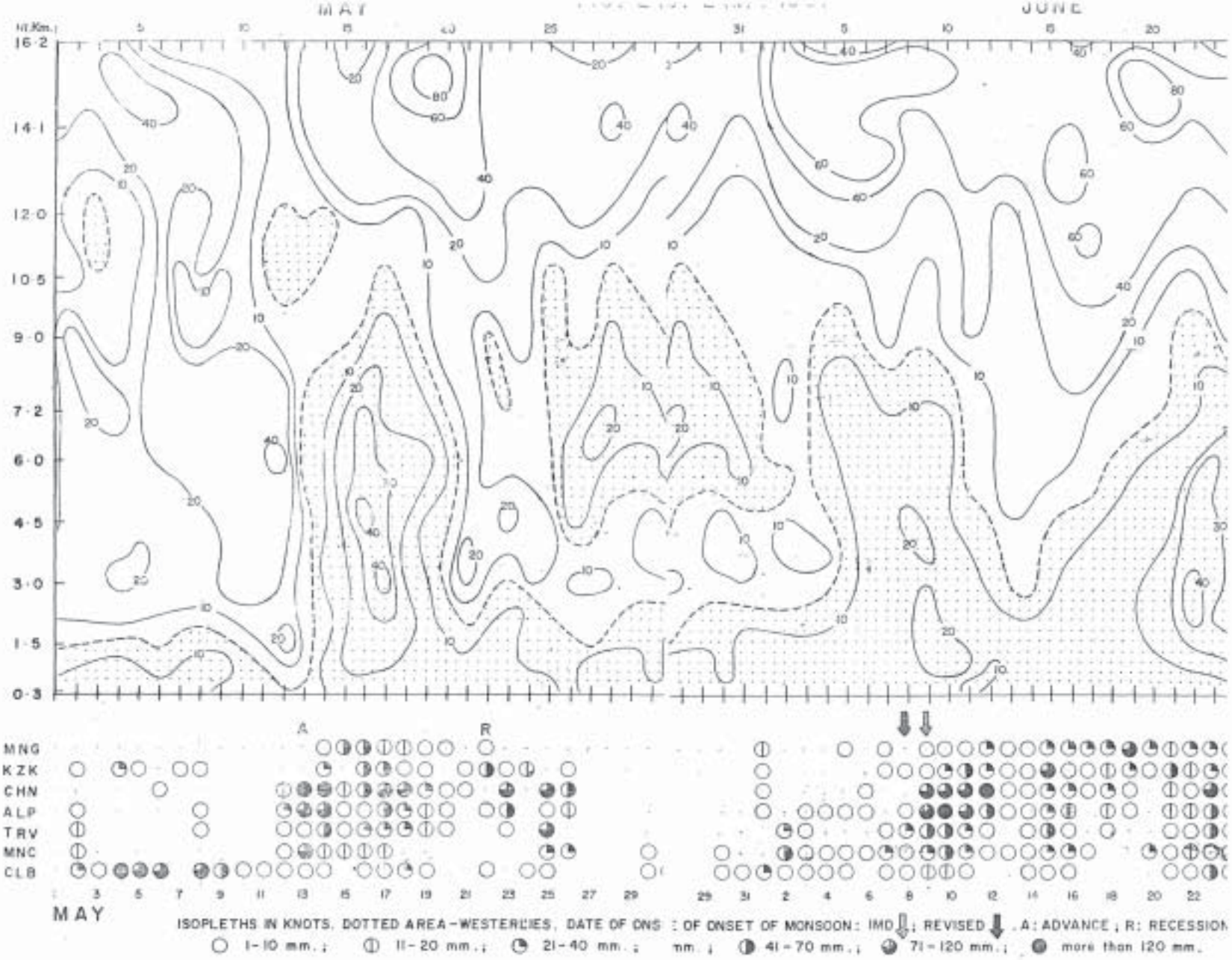


FIG. 2 (viii) : 1965
MAY
JUNE
ZONAL WINDS OVER TRIVANDRUM
RAINFALL
A
R
NG
ZK
HN
VP
RV
INC
LB


MAY
FIG. 2 (ix) : 1966
JUNE
Ht.Km.
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
MNG
KZK
CHN
ALP
TRV
MNC
CLB
MAY
ISOPLETHS IN KNOTS. DOTTED AREA-WESTERLIES. DATE OF ONSET OF MONSOON : IMD ⇩ ; REVISED ⇩ . A: ADVANCE ; R: RECESSION


MAY
JUNE
(H.Km.)
16·2
14·1
12·0
10·5
9·0
7·2
6·0
4·5
3·0
1·5
0·3
A
R
MNG
KZK
CHN
ALP
TRV
MNC
CLB
MAY
ISOPLETHS IN KNOTS, DOTTED AREA-WESTERLIES, DATE OF ONS : OF ONSET OF MONSOON: IMD ⇩; REVISED ⇩ . A: ADVANCE ; R: RECESSION
○ 1-10 mm.; ◑ 11-20 mm.; ◔ 21-40 mm.; nm. ; ◑ 41-70 mm.; ◕ 71-120 mm.; ● more than 120 mm.

UPPER WINDS : NEW DELHI

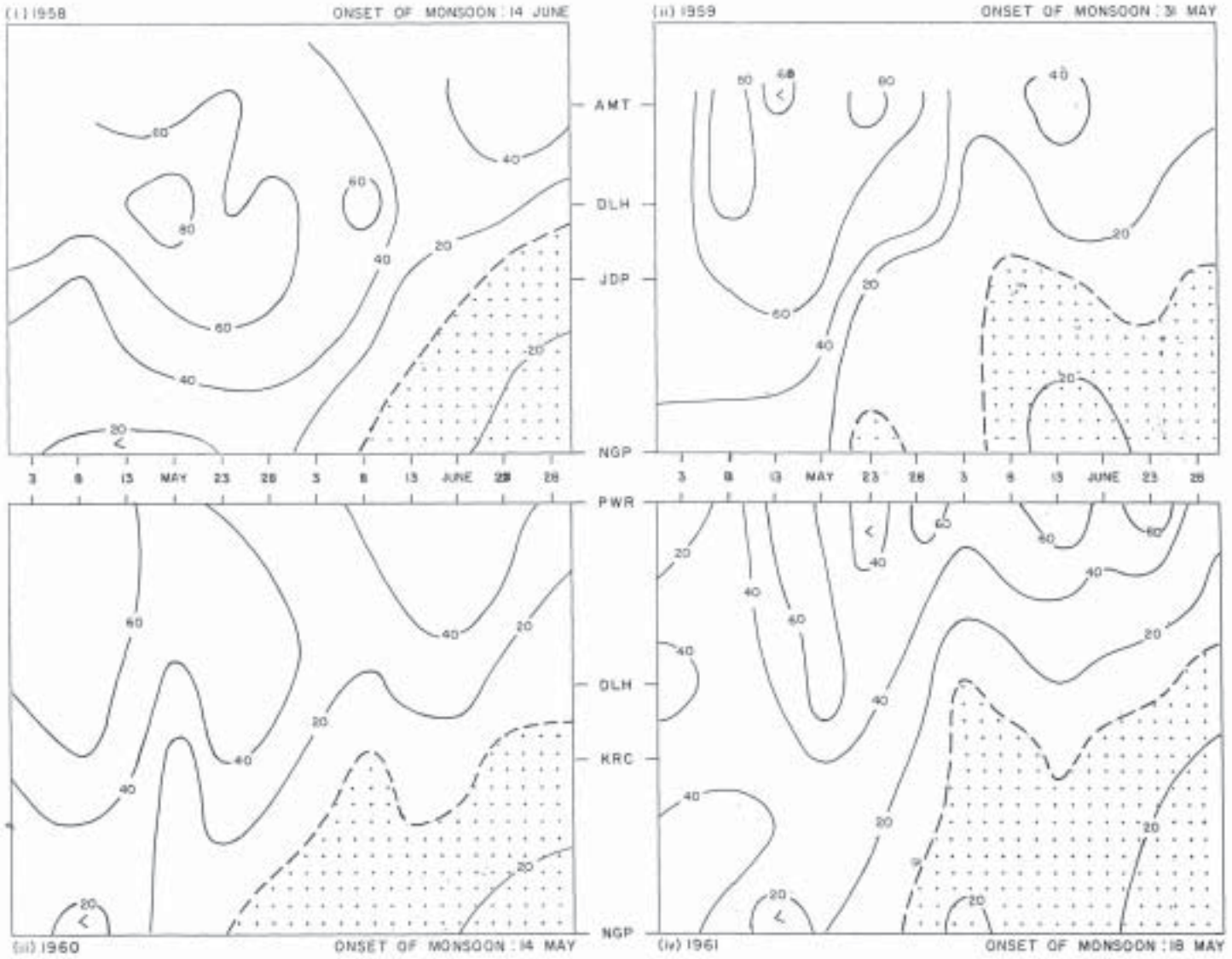

(i) 1958
ONSET OF MONSOON : 14 JUNE
(ii) 1959
ONSET OF MONSOON : 31 MAY
AMT
DLH
JDP
NGP
3 8 13 MAY 23 28 3 8 13 JUNE 23 28
PWR
DLH
KRC
NGP
(iii) 1960
ONSET OF MONSOON : 14 MAY
(iv) 1961
ONSET OF MONSOON : 18 MAY

FIG. 6

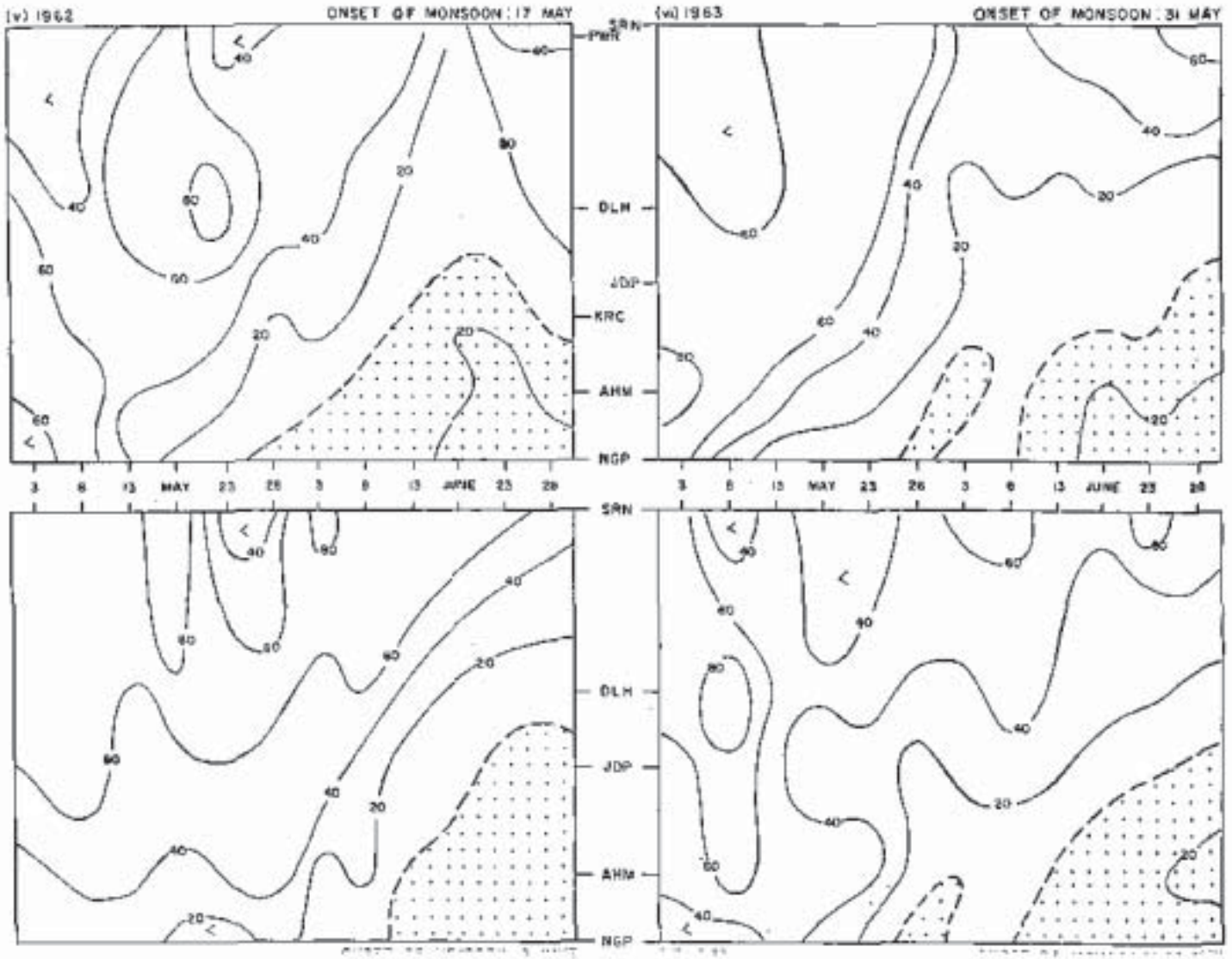
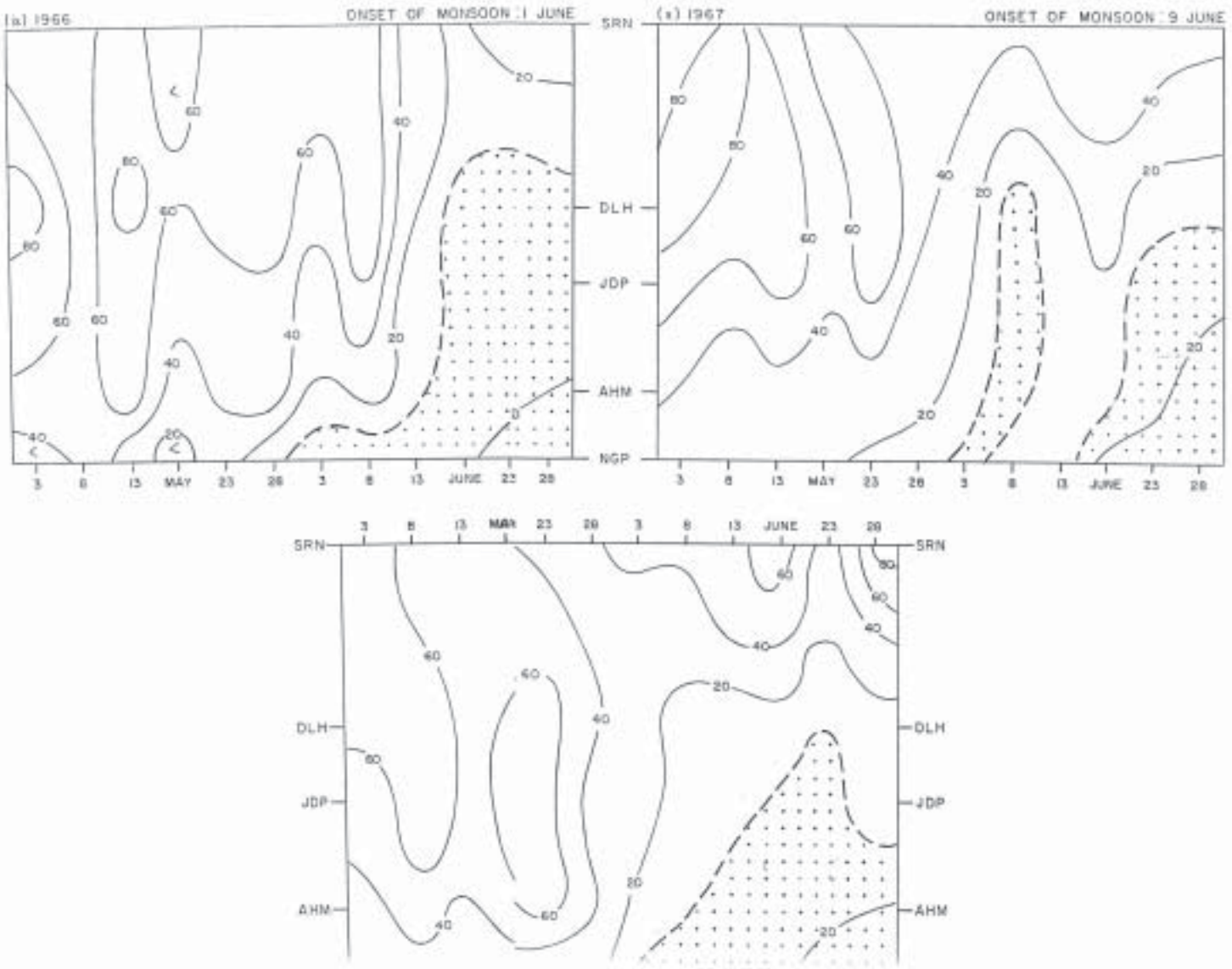

(v) 1962
ONSET OF MONSOON : 17 MAY
(vi) 1963
ONSET OF MONSOON : 31 MAY
SRN
PBR
DLH
JDP
KRC
AHM
NGP
3 8 13 MAY 23 28 3 8 13 JUNE 23 28

FIG. 4


(a) 1966
ONSET OF MONSOON : 1 JUNE
(x) 1967
ONSET OF MONSOON : 9 JUNE
SRN
DLH
JDP
AHM
NGP
3 8 13 MAY 23 28 3 8 13 JUNE 22 28
3 8 13 MAY 23 28 3 8 13 JUNE 23 28
3 8 13 MAY 23 28 3 8 13 JUNE 23 28
SRN
DLH
JDP
AHM
60
40
20
0

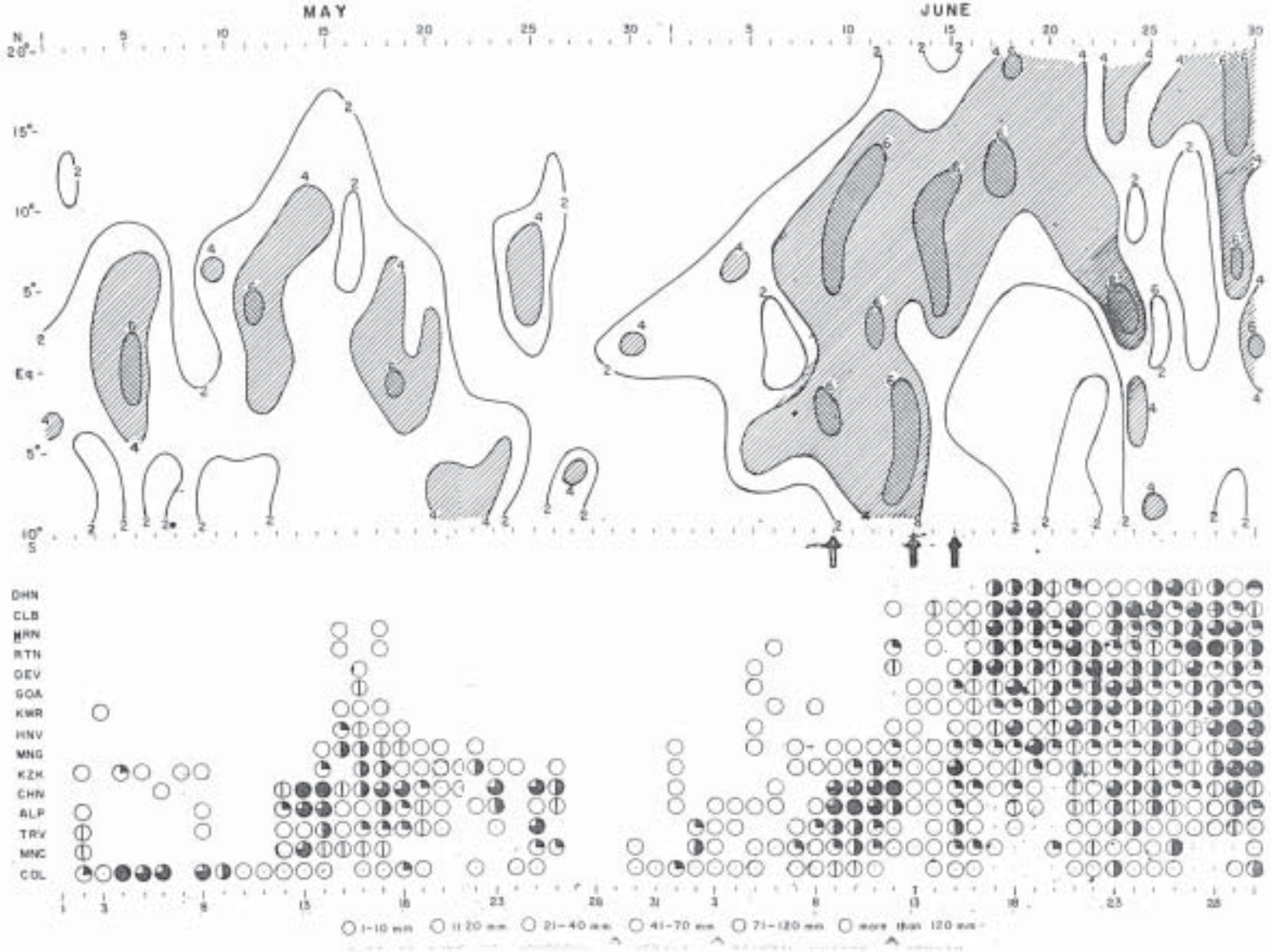
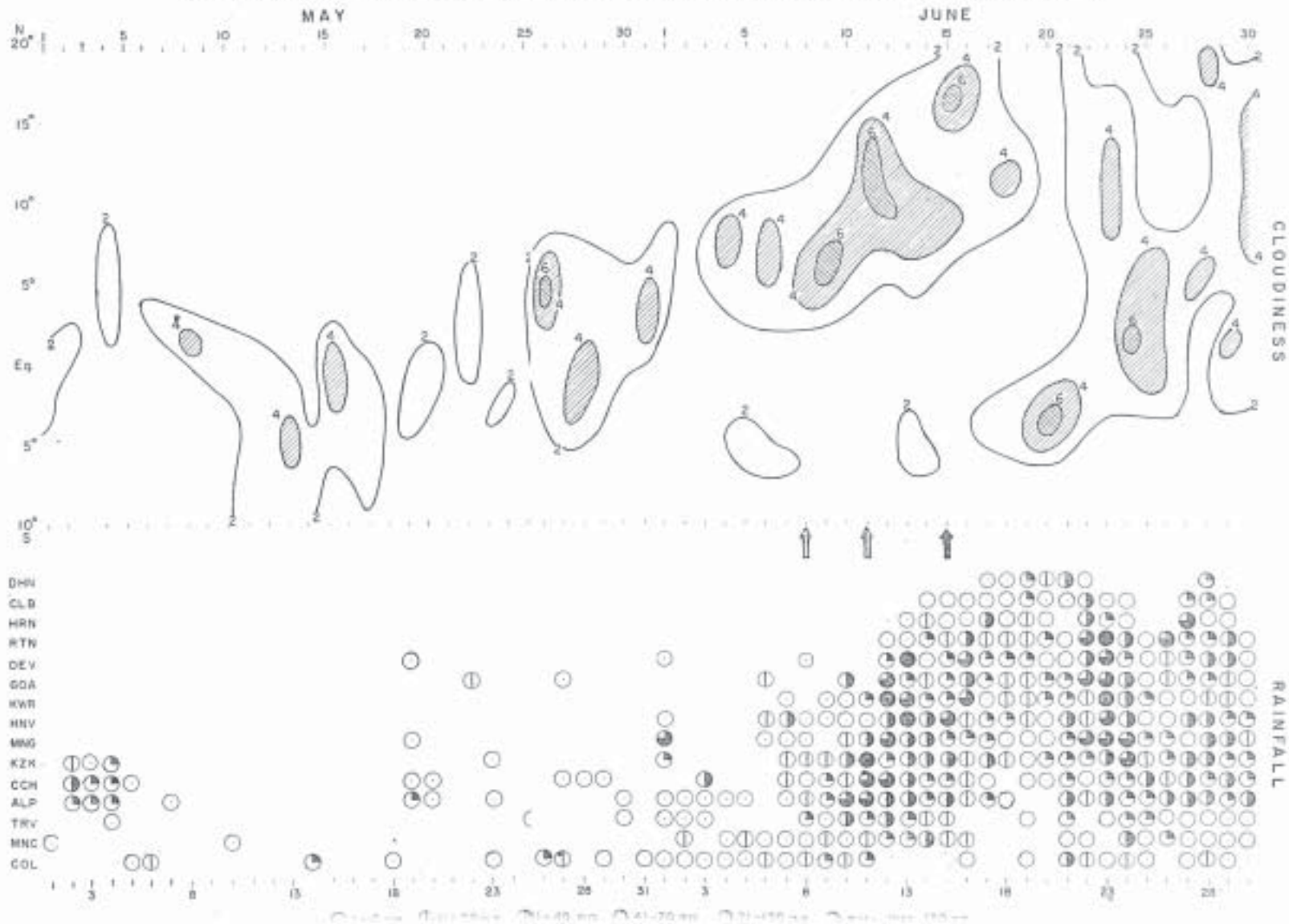

MAY
JUNE
N
20°
15°
10°
5°
Eq
5°
10°
S
DHN
CLB
MRN
RTN
OEV
GOA
KWR
HNV
MNG
KZH
CHN
ALP
TRV
MNC
COL
1-10 mm
11-20 mm
21-40 mm
41-70 mm
71-120 mm
more than 120 mm

FIG.-5(ii) MEAN CLOUDINESS OVER THE ARABIAN SEA AND WEST-COAST RAINFALL, MAY-JUNE 1968



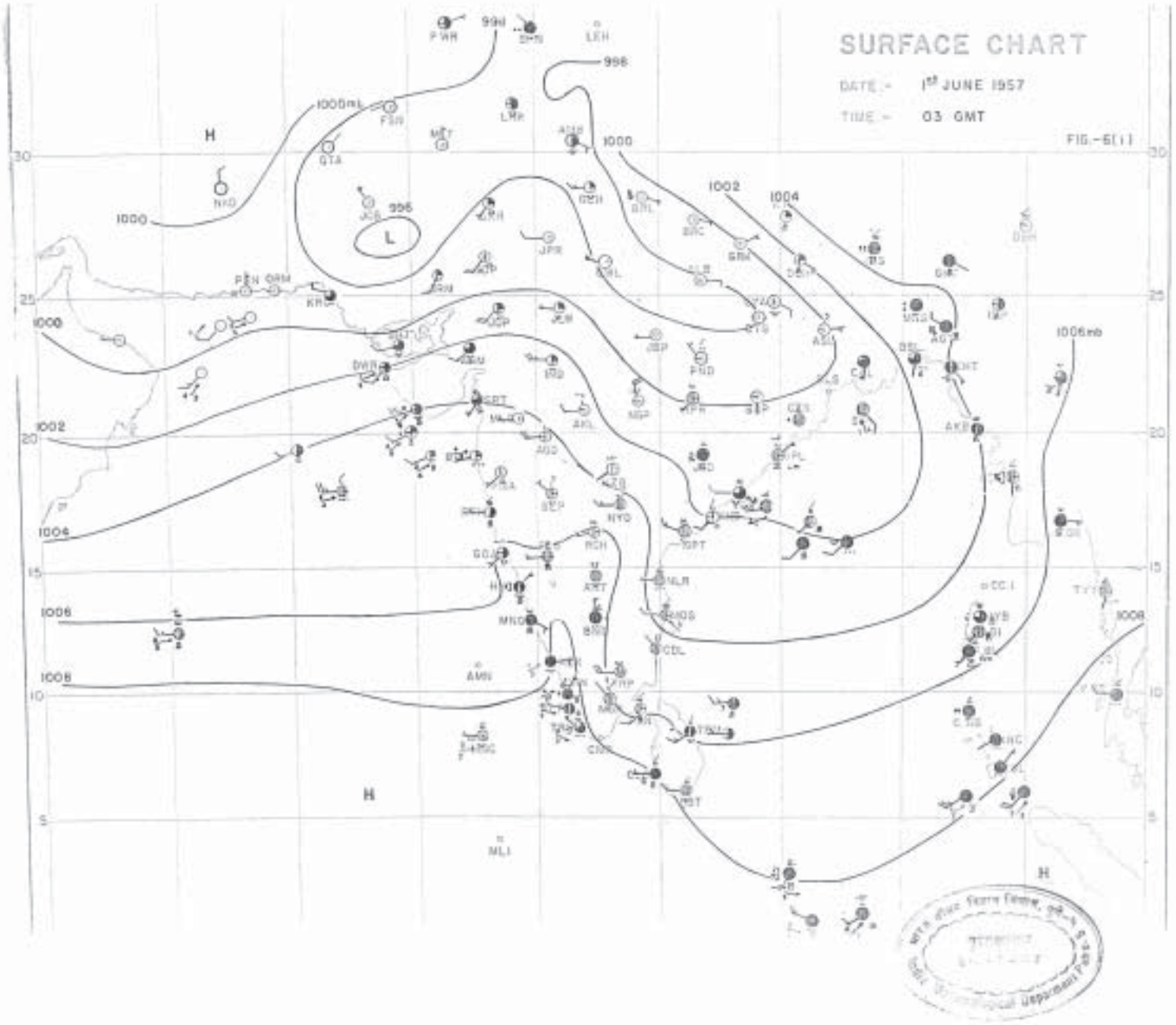
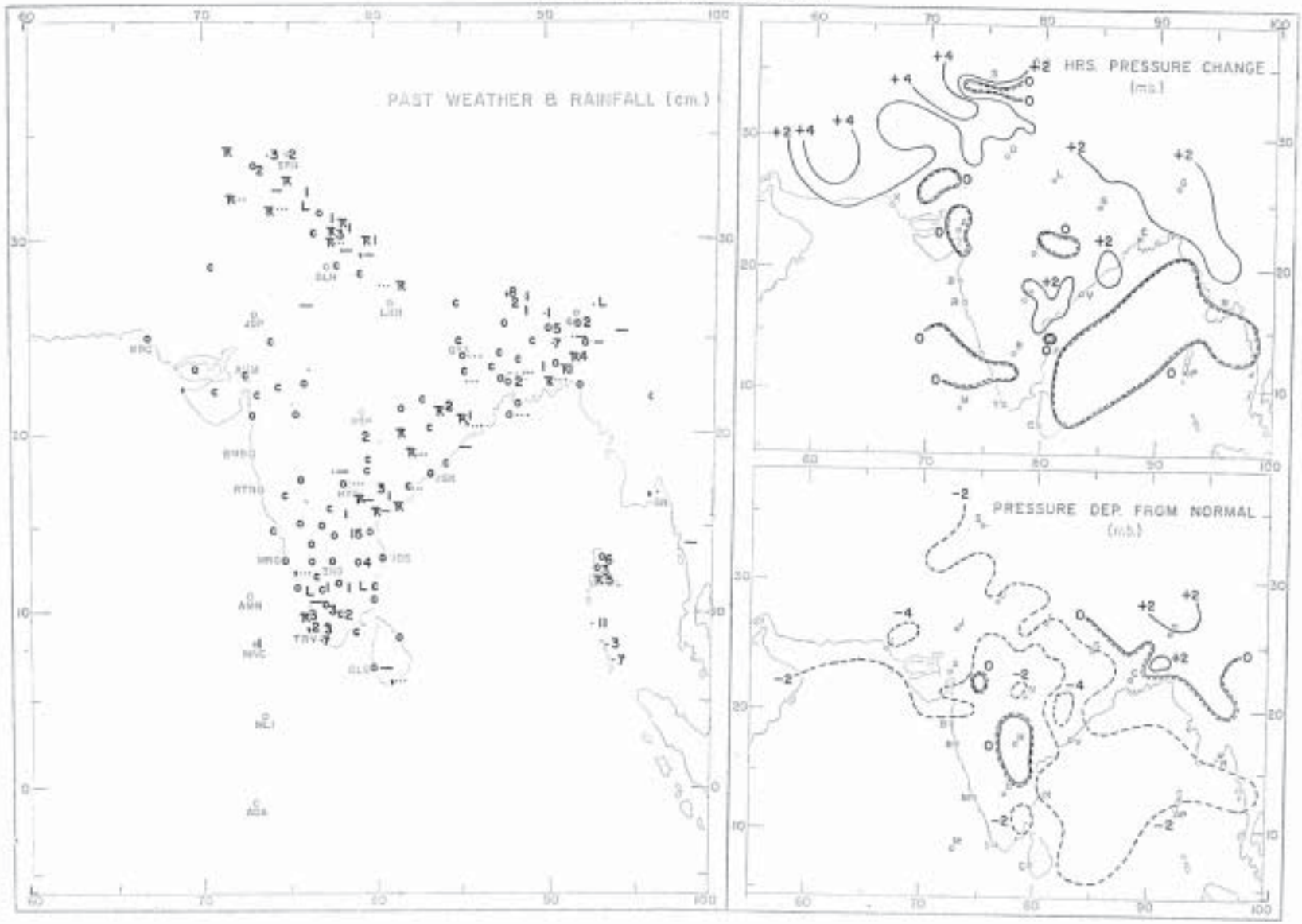
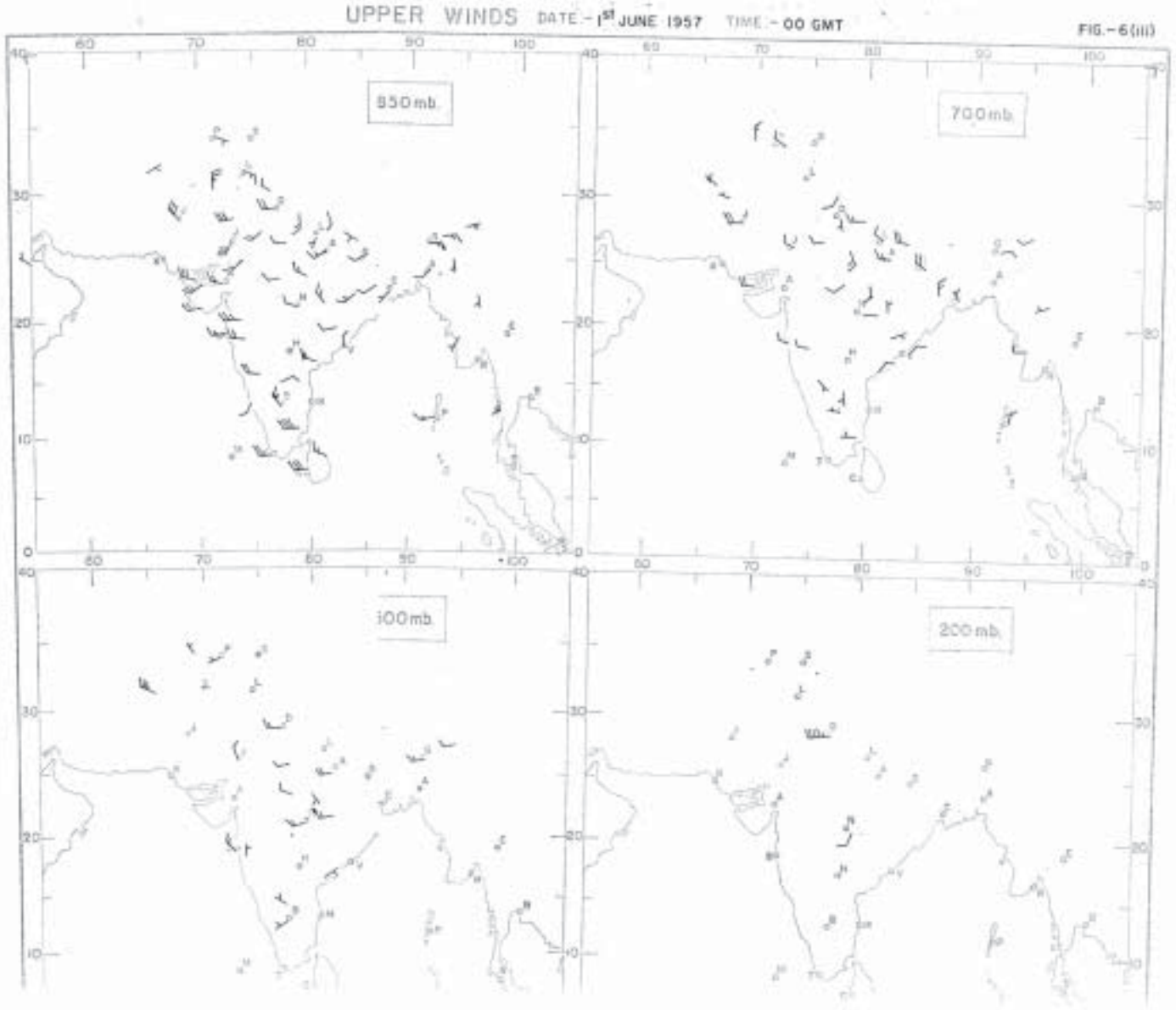

SURFACE CHART
DATE :- 1st JUNE 1957
TIME :- 03 GMT
FIG.-6(i)
1000mb
1002
1004
1006
1008
H
L
996
998
1000
1006mb

FIG.-6(ii)

DATE :-1ST JUNE 1957 TIME :-03 GMT




UPPER WINDS DATE - 1ST JUNE 1957 TIME - 00 GMT
FIG.-6(iii)
850 mb.
700 mb.
100 mb.
200 mb.

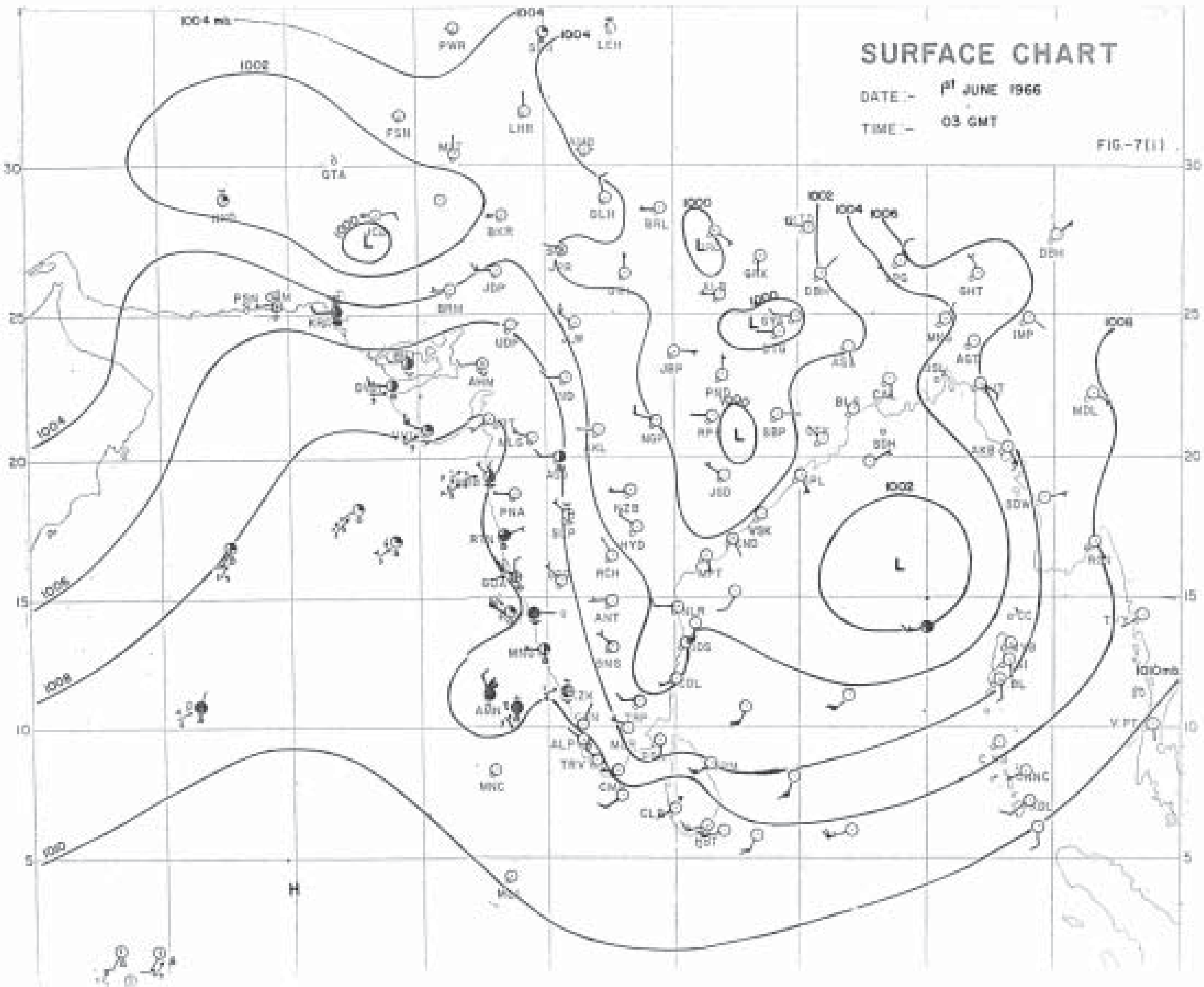
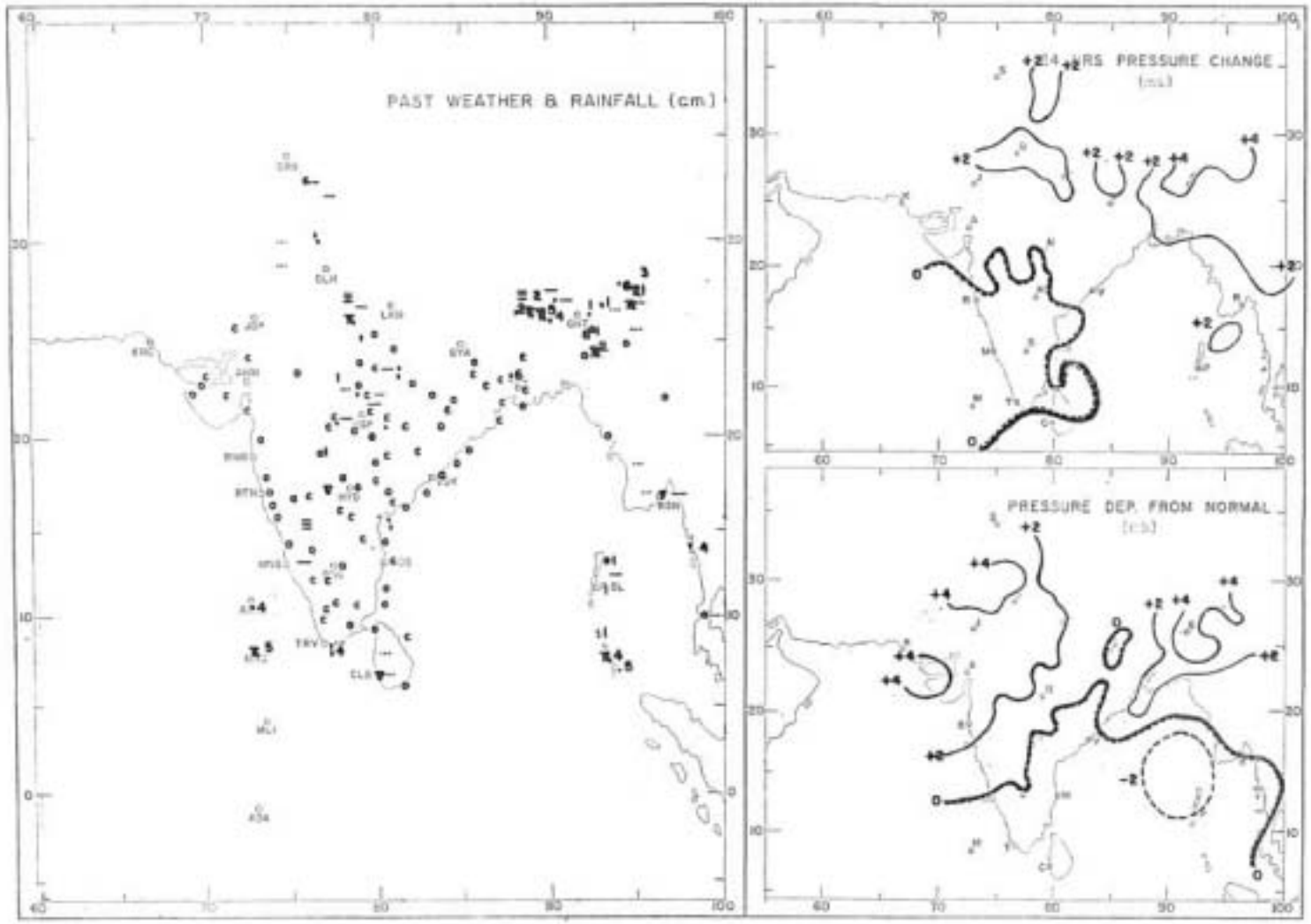
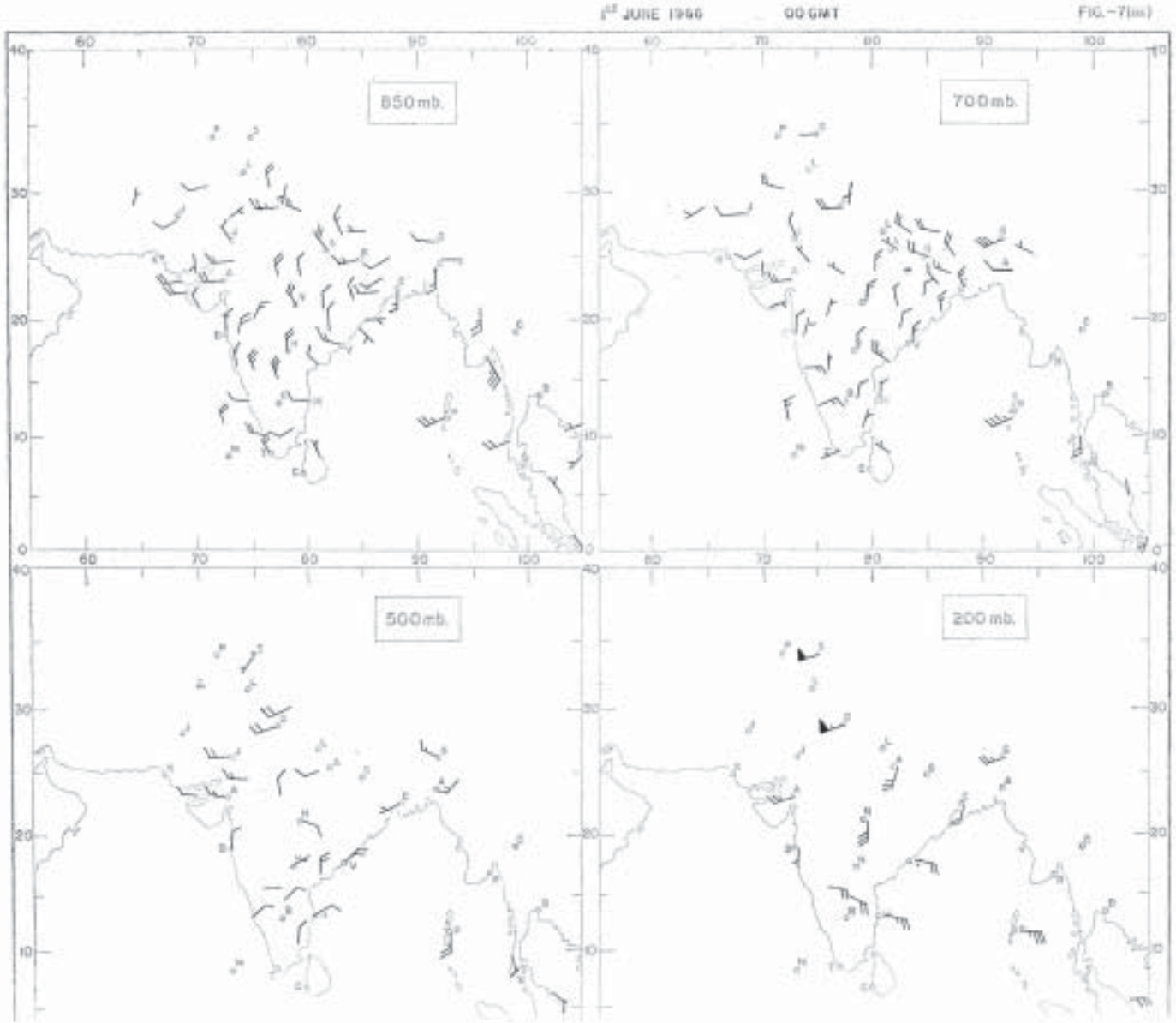

SURFACE CHART
DATE :- 1st JUNE 1966
TIME :- 03 GMT
FIG.-7(1)
1004 mb
1004
1002
1000
1006
1008
1010
1010mb
L
H
30
25
20
15
10
5
PWR
LEH
FSN
LHR
QTA
DLH
BRL
BKR
JDP
BRM
UDP
AHM
NGP
JBP
SBP
GHT
AGT
IMP
MDL
DBH
NKI
PNA
RTN
GOA
MNG
AGN
ANT
HYD
RCH
NZB
VSK
NLR
MDS
CDL
ALP
TRV
CLB
MNC
AKB
SDW
RGN
V.PT

FIG.-7(iii)

DATE:- 1ST JUNE 1966 TIME - 03 GMT




1ST JUNE 1966
00 GMT
FIG.-7(iii)
850 mb.
700 mb.
500 mb.
200 mb.

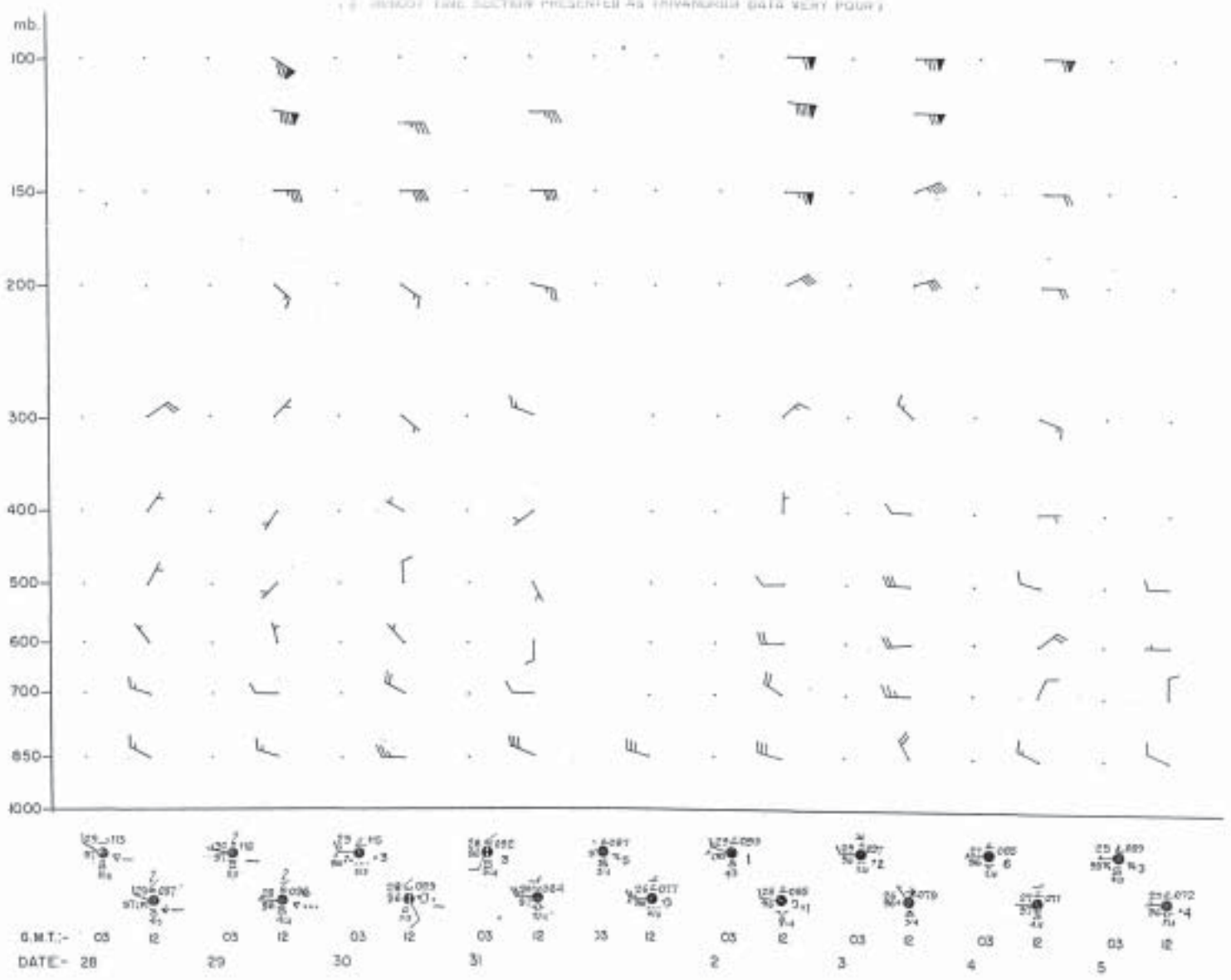
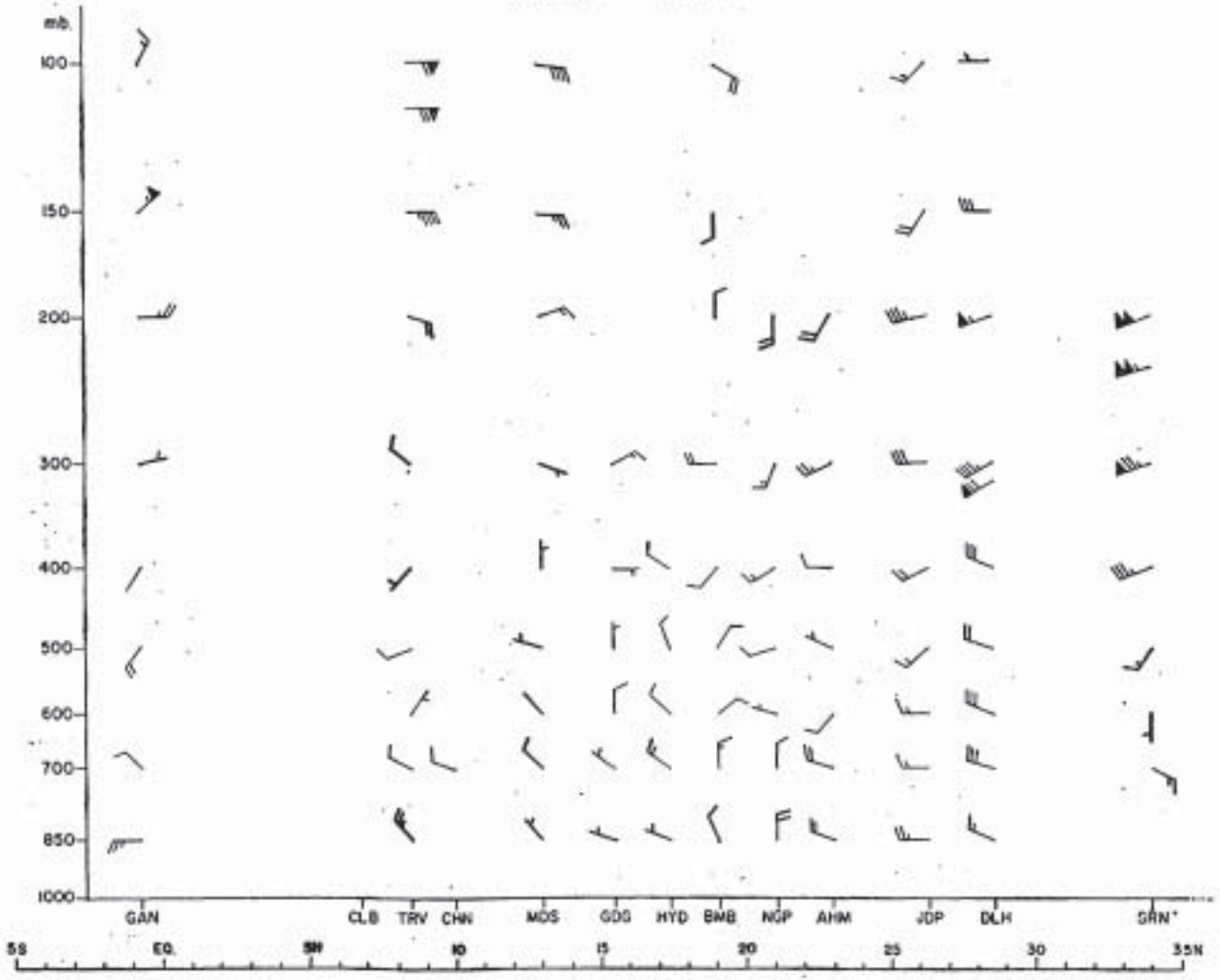
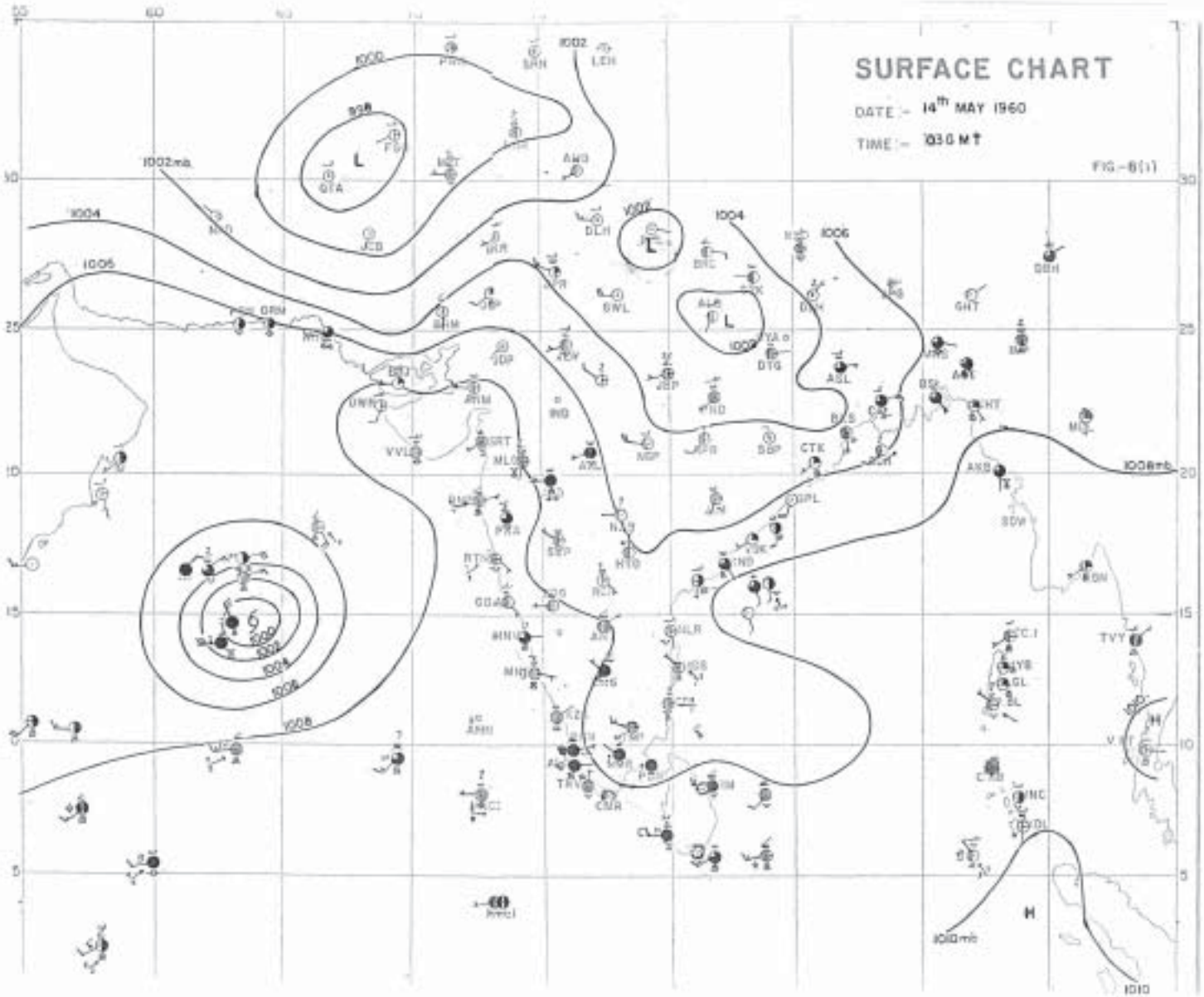

mb.
100
150
200
300
400
500
600
700
850
1000
G.M.T.:- 03 12 03 12 03 12 03 12 03 12 03 12 03 12 03 12 03 12
DATE:- 28 29 30 31 2 3 4 5

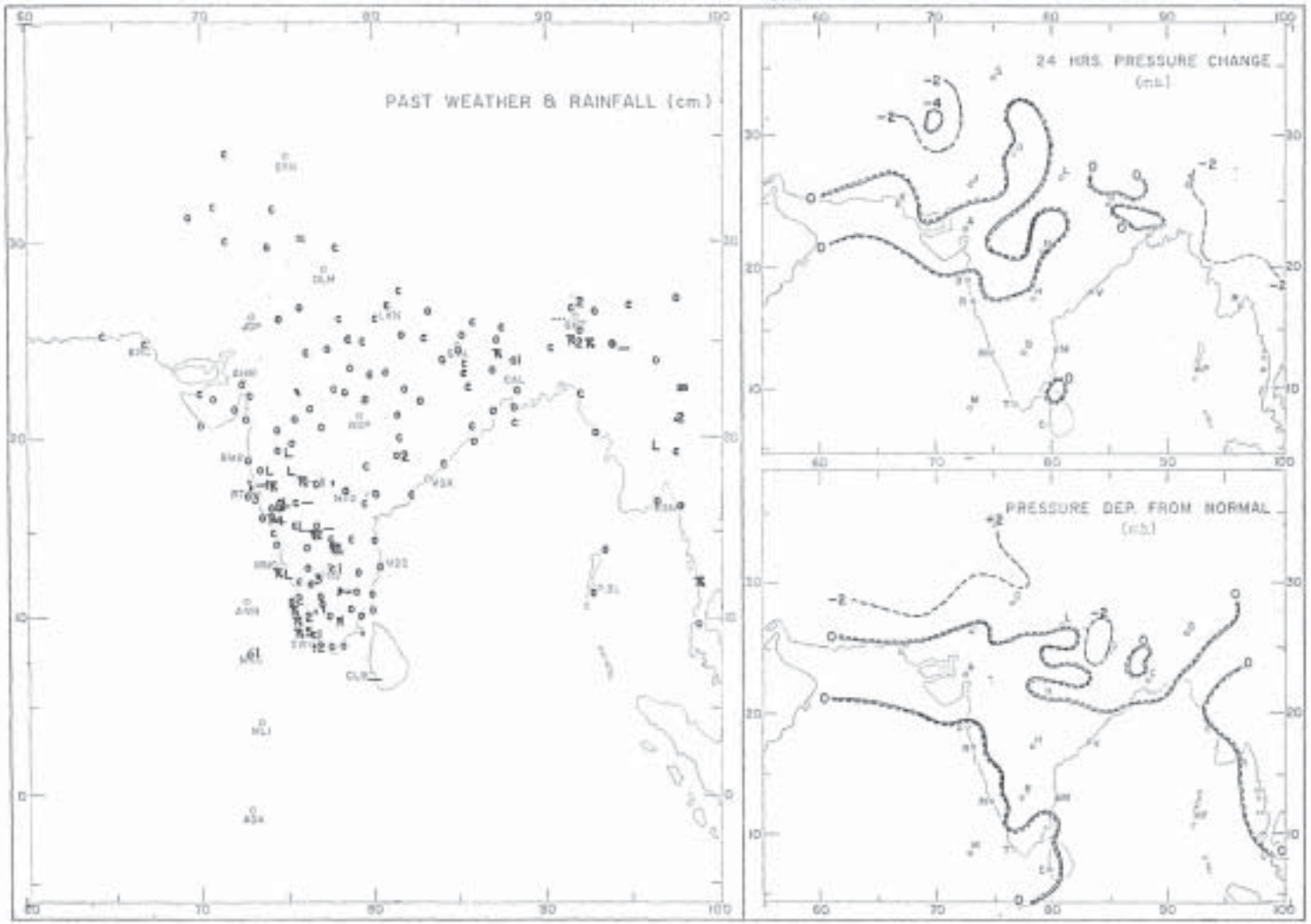
FIG. 7(v) VERTICAL CROSS-SECTION ACROSS INDIA

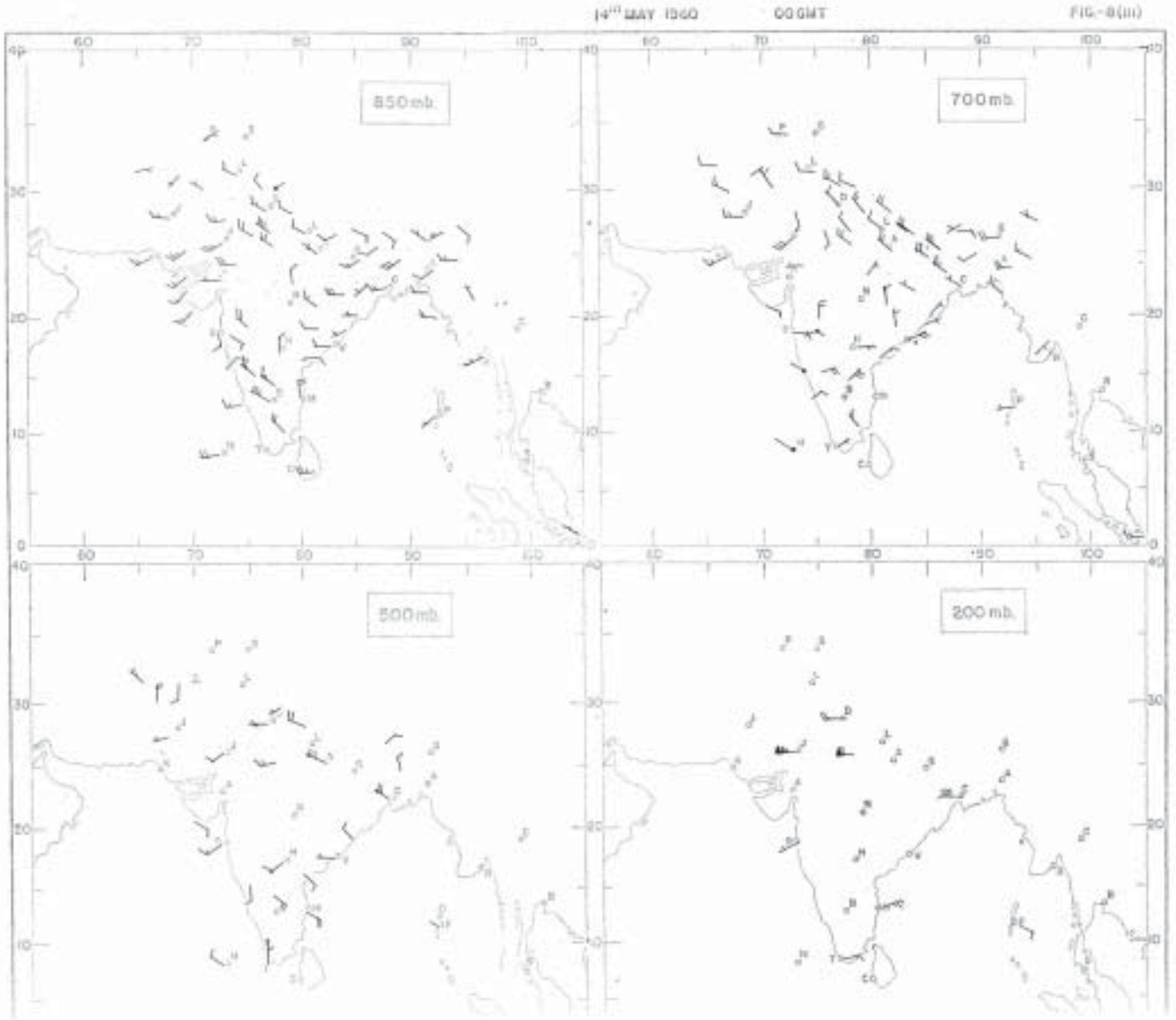
31 MAY 1966. 12 GMT.




SURFACE CHART
DATE :- 14th MAY 1960
TIME :- 1030 GMT
FIG-6(1)
1002mb
1004
1006
1008mb
1010

DATE :- 14 MAY 1960 TIME 03 GMT




14TH MAY 1960 00 GMT
FIG.-8(iii)
850 mb.
700 mb.
500 mb.
200 mb.

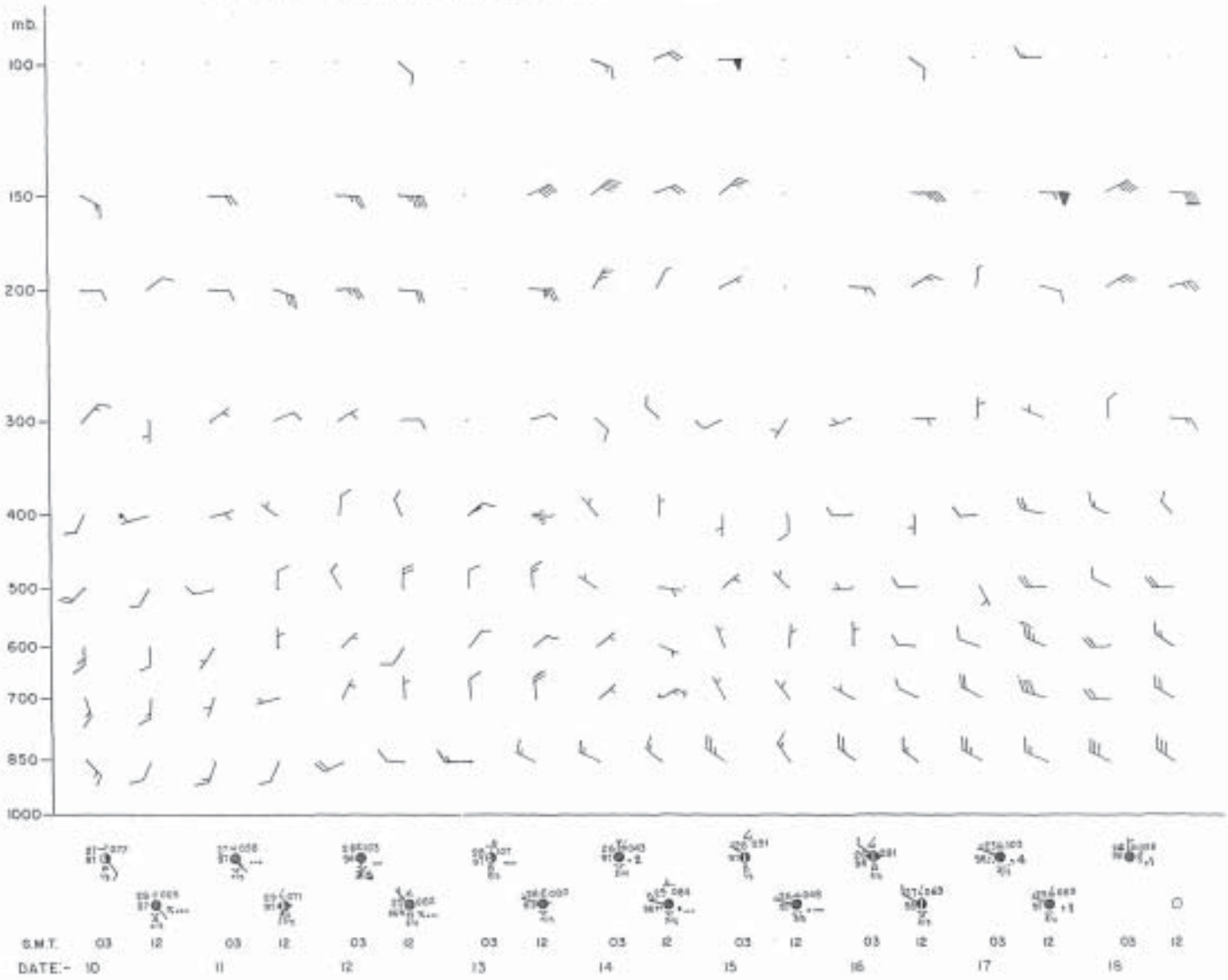
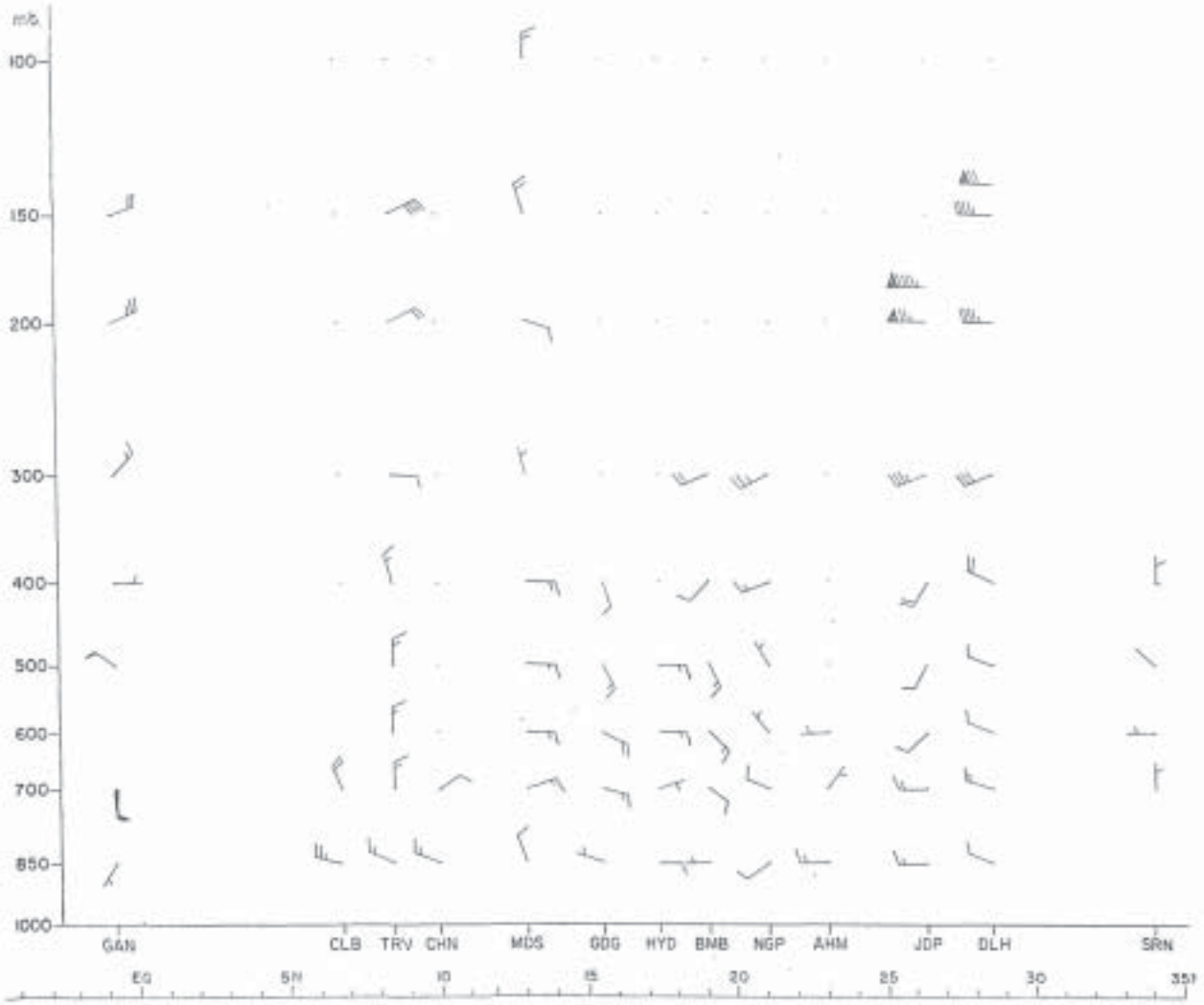

mb.
100
150
200
300
400
500
600
700
850
1000
G.M.T. 03 12 03 12 03 12 03 12 03 12 03 12 03 12 03 12 03 12
DATE:- 10 11 12 13 14 15 16 17 18

FIG. 8(v) VERTICAL CROSS-SECTION ACROSS INDIA

13 MAY 1960. 12 GMT



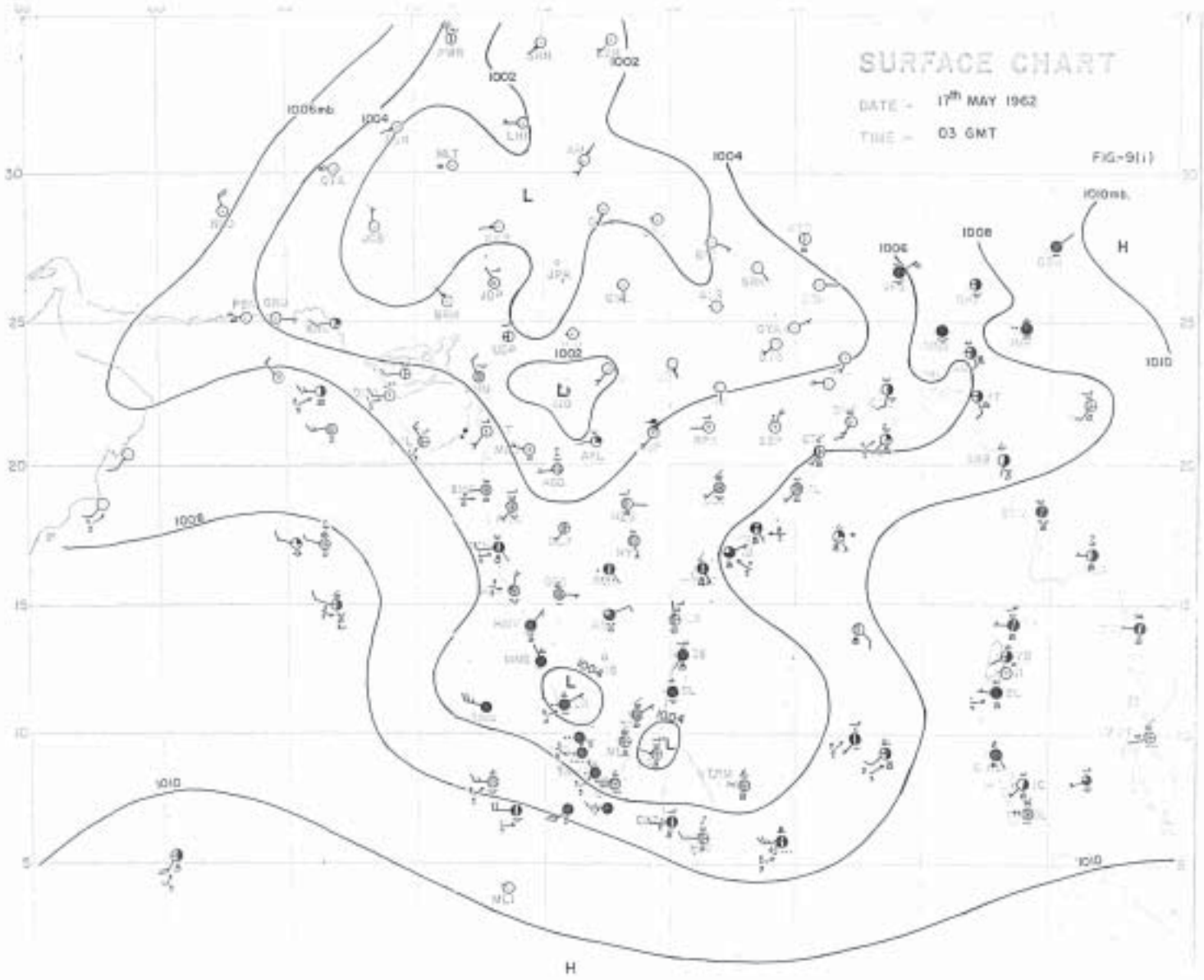
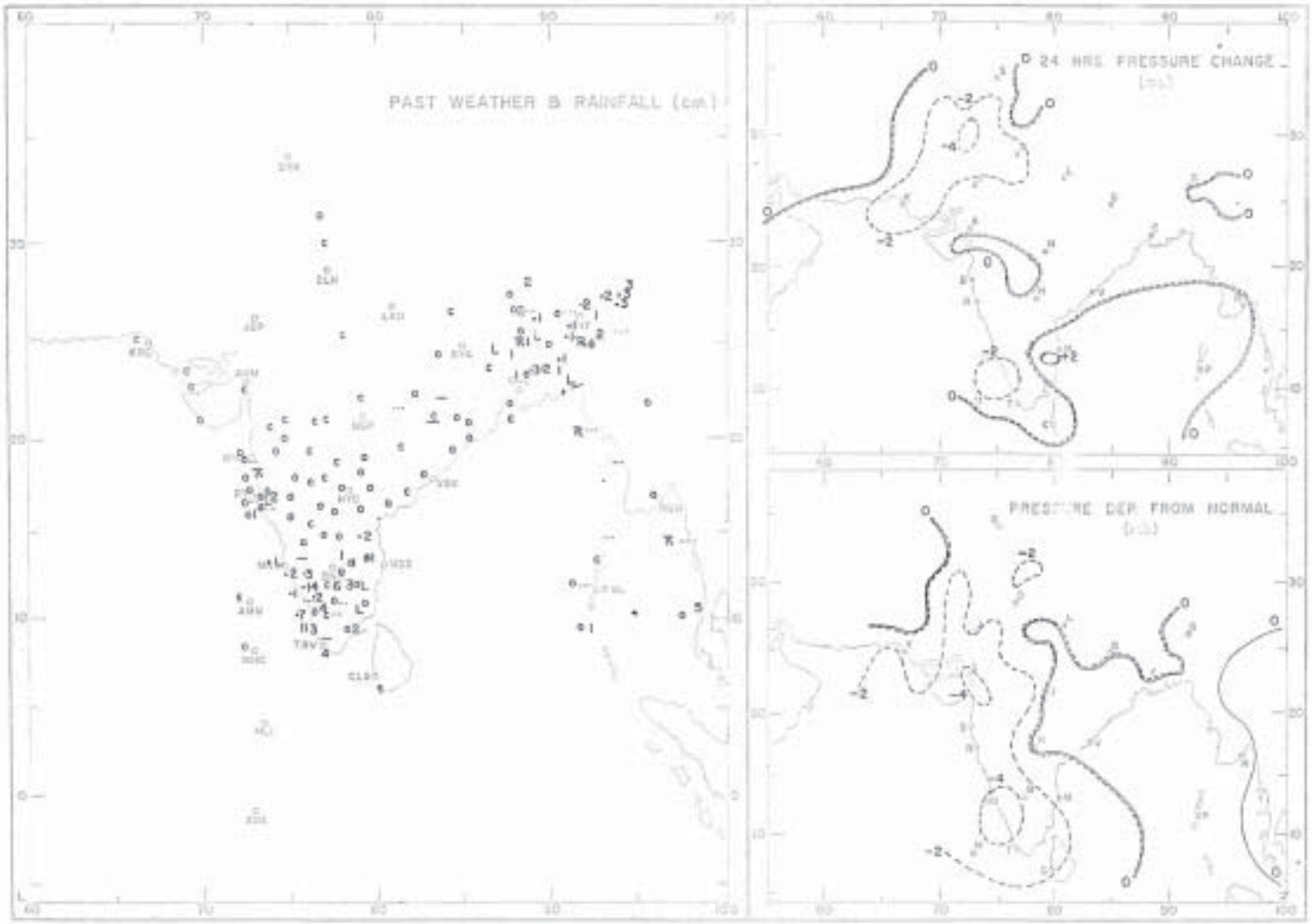

SURFACE CHART
DATE - 17th MAY 1962
TIME - 03 GMT
FIG-9(i)
1002
1004
1006mb
1008
1010mb.
1010
L
H

FIG.-9(ii)

DATE : 17th MAY 1962 TIME 03 GMT



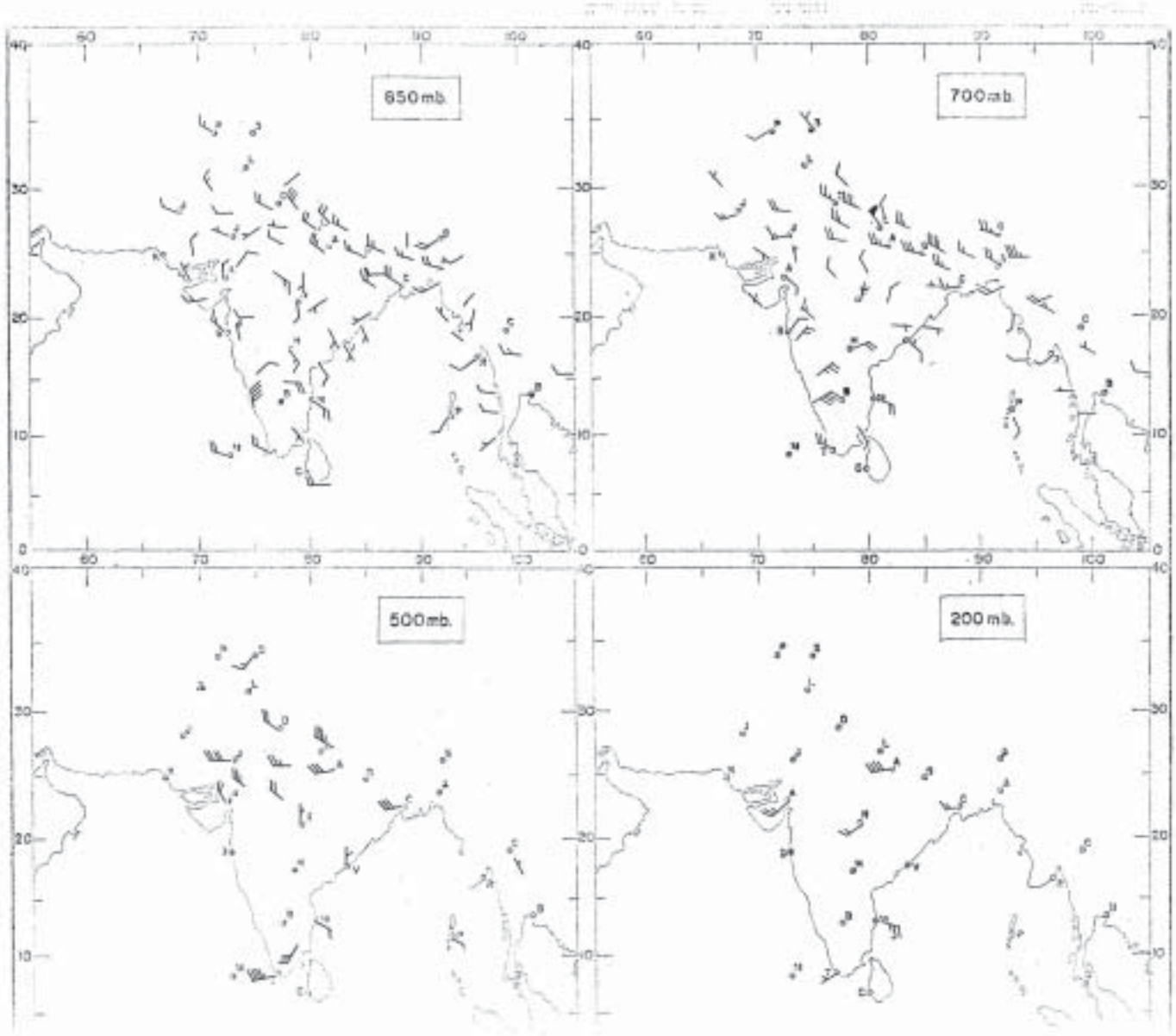

650mb.
700mb.
500mb.
200mb.

FIG. 9 (iv) VERTICAL TIME SECTION - TRIVANDRUM (13 MAY TO 21 MAY 1962)

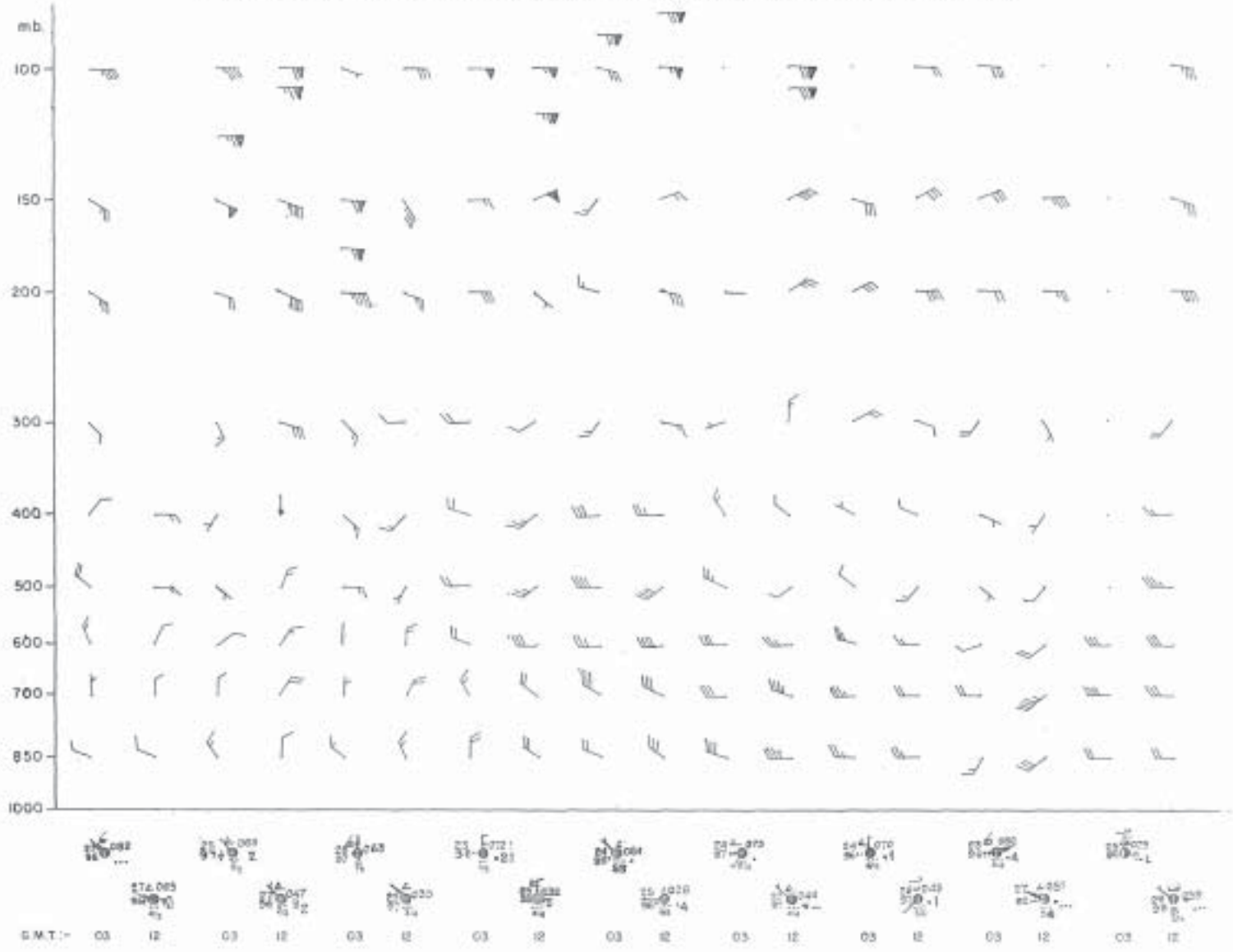
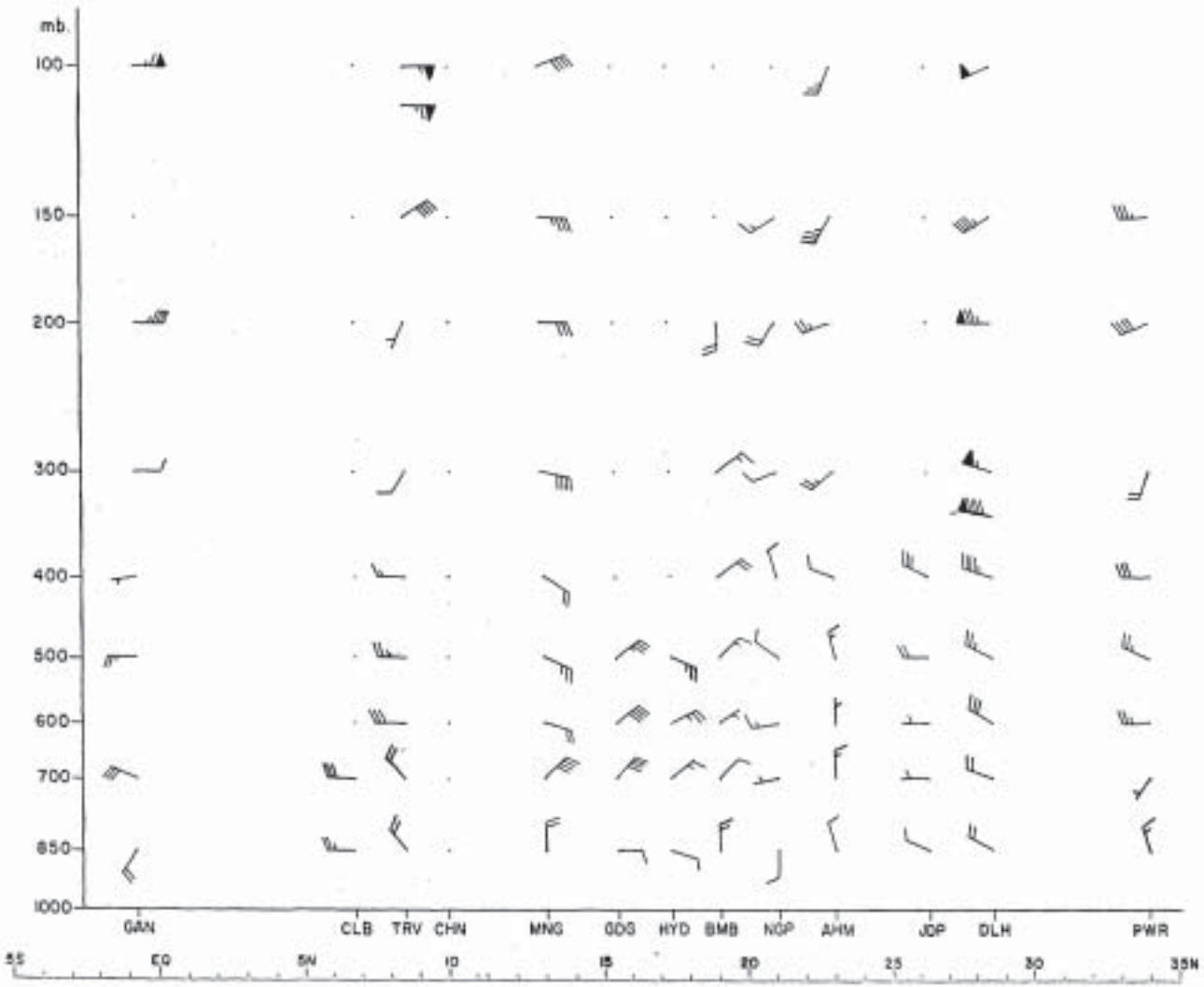


FIG.9(v) VERTICAL CROSS-SECTION ACROSS INDIA

16 MAY 1962. 12 GMT



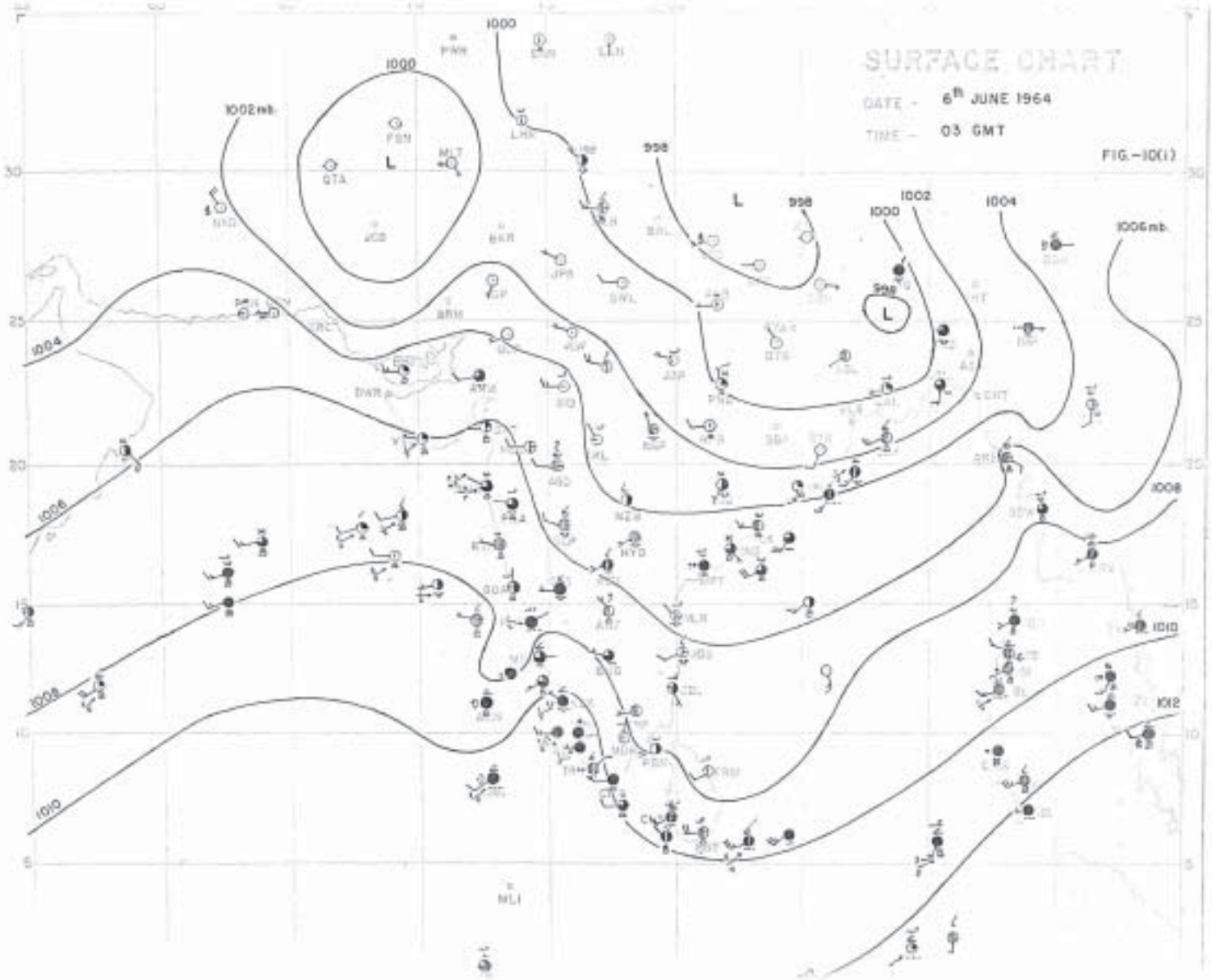
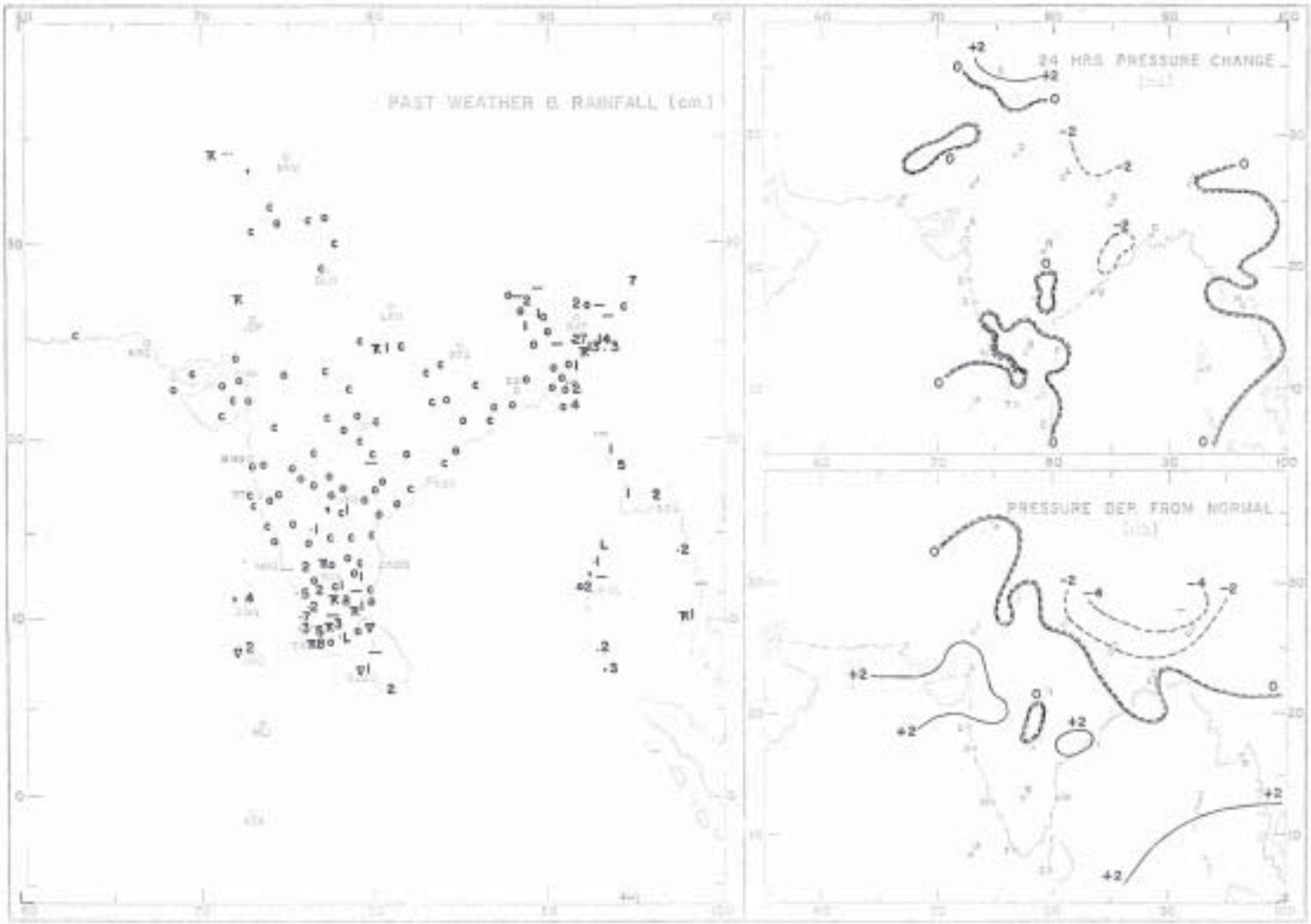

SURFACE CHART
DATE - 6th JUNE 1964
TIME - 03 GMT
FIG.-10(i)
1000
1002mb.
1004
1006
1008
1010
1012
998
1002
1004
1006mb.
L

FIG-10(ii)

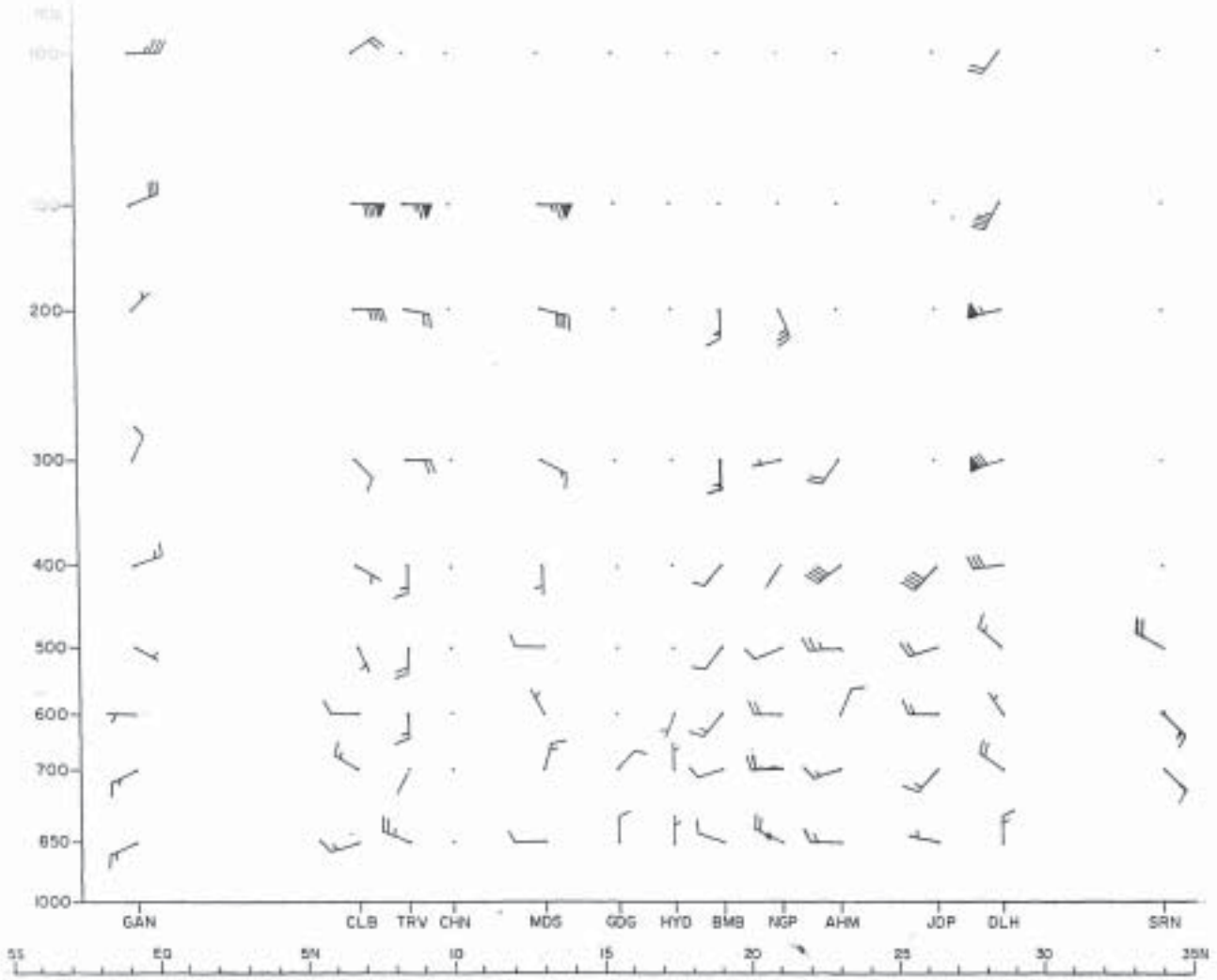
DATE 6th JUNE 1964 TIME 03 GMT

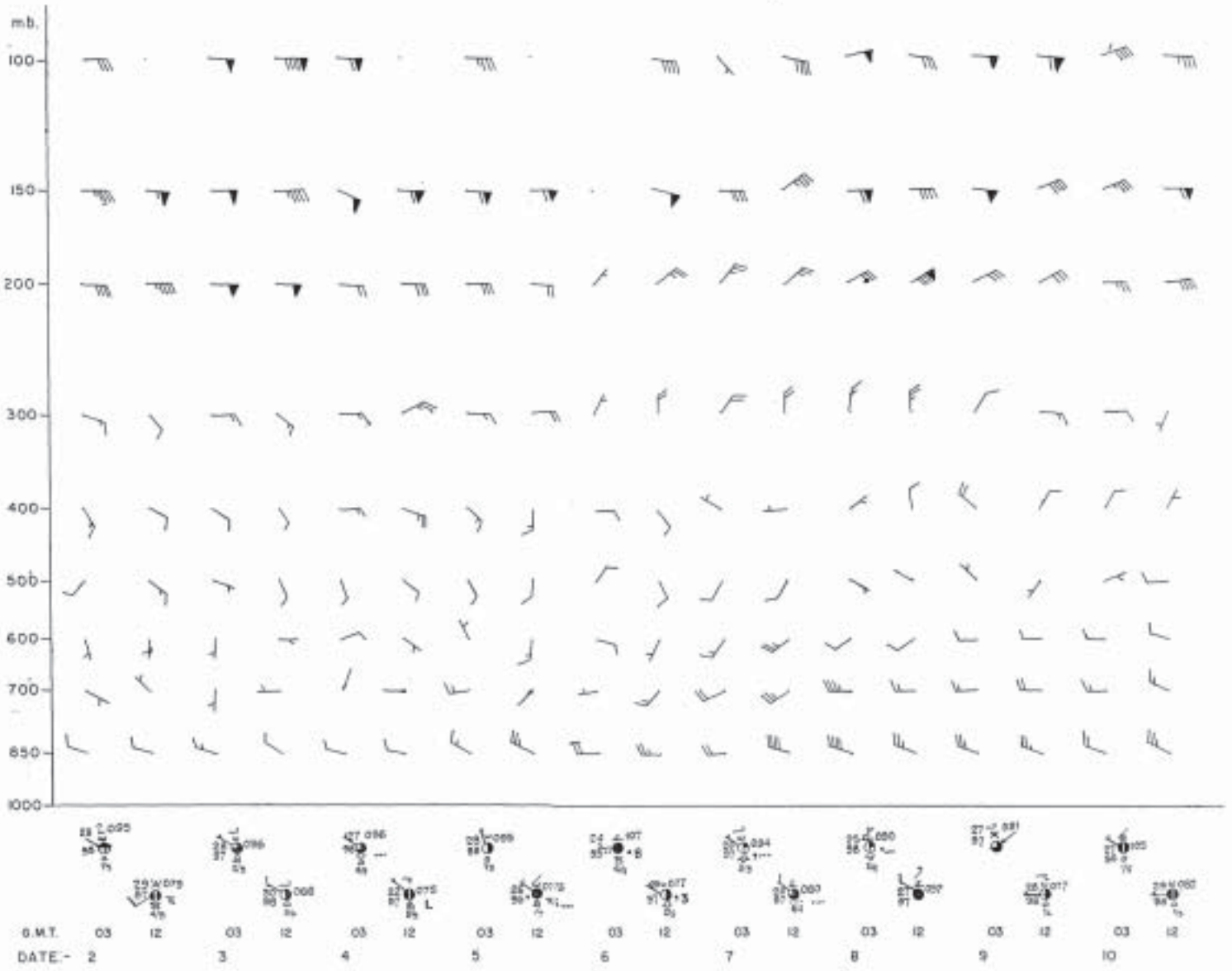


6TH JUNE 1964 00 GMT FIG.-I(Contd)

FIG.10(v) VERTICAL CROSS-SECTION ACROSS INDIA

5 JUNE 1964. 12 GMT




m.b.
100
150
200
300
400
500
600
700
850
1000
G.M.T. 03 12 03 12 03 12 03 12 03 12 03 12 03 12 03 12 03 12
DATE:- 2 3 4 5 6 7 8 9 10

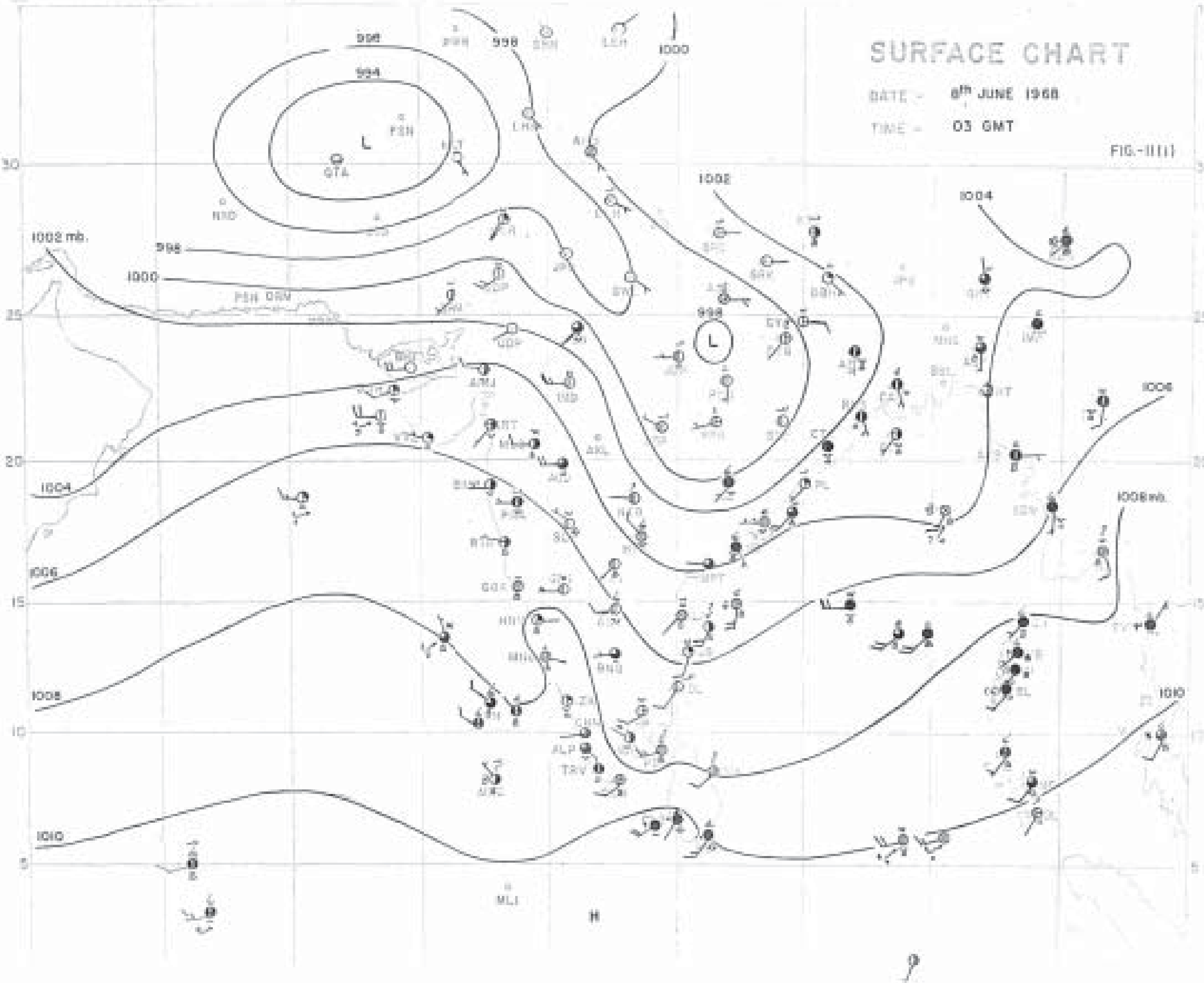
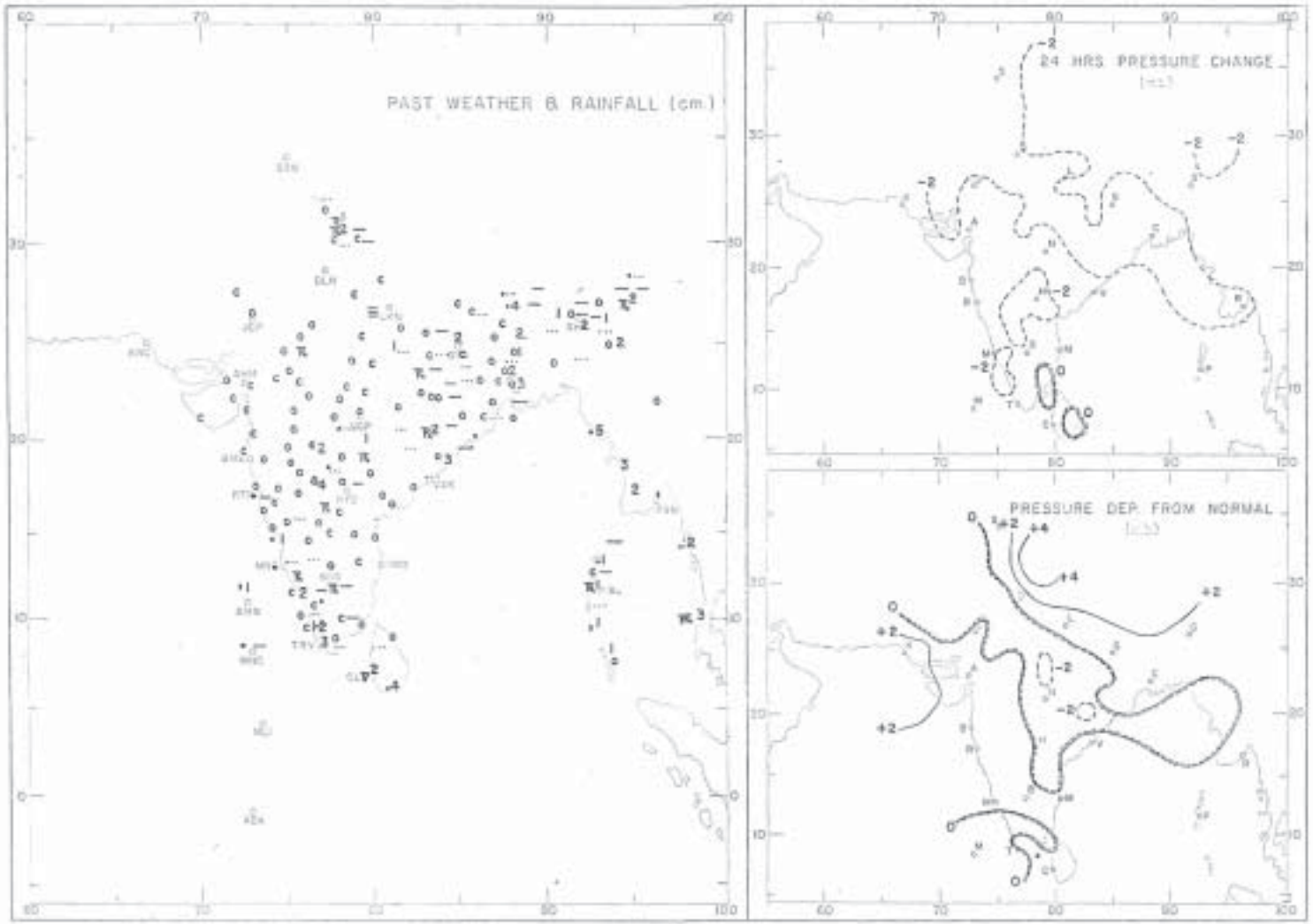

SURFACE CHART
DATE - 8th JUNE 1968
TIME - 03 GMT
FIG.-II(i)

FIG.-II (a)

DATE :- 8th JUNE 1968 TIME - 03 GMT



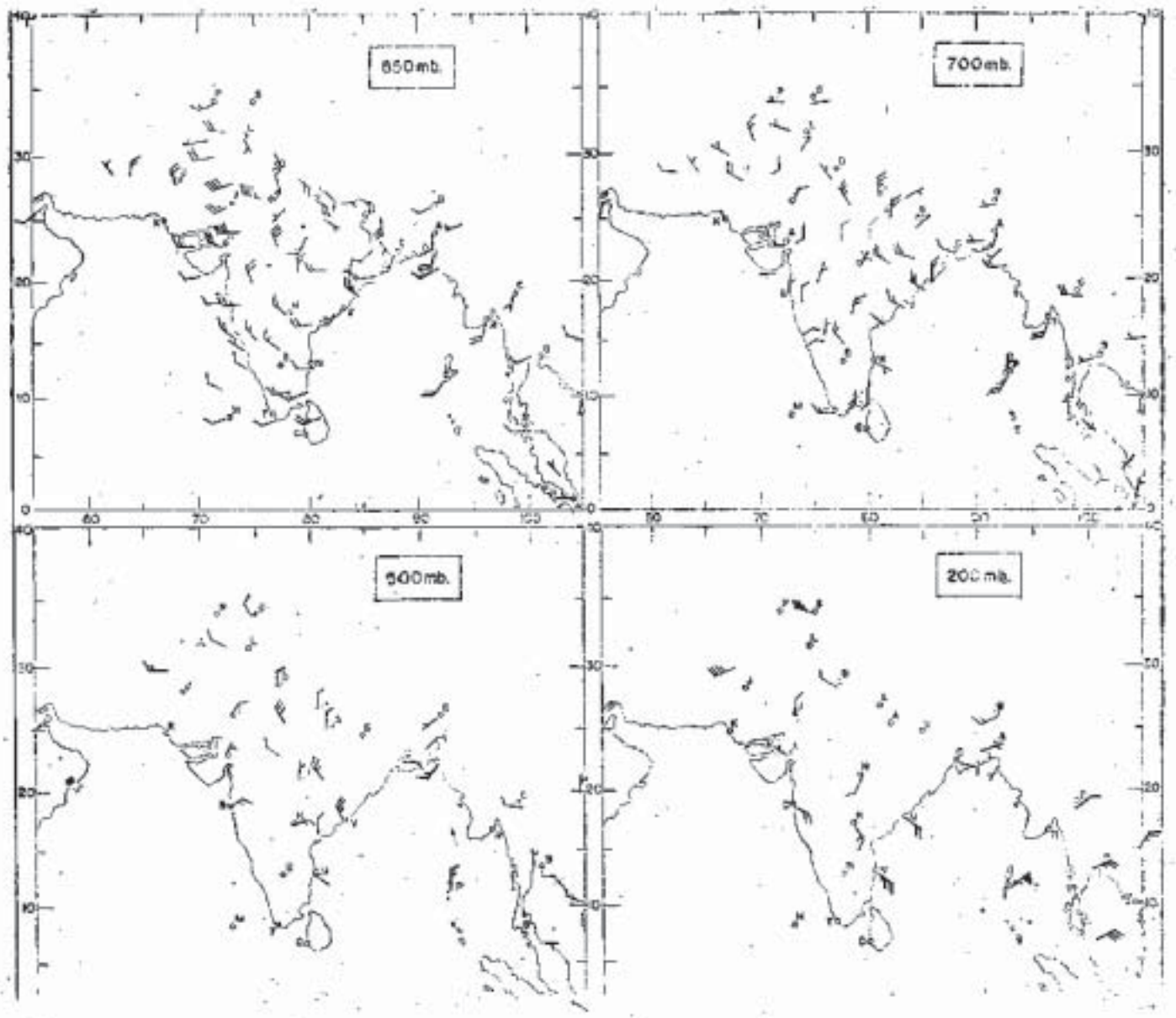

850mb.
700mb.
500mb.
200 mb.

FIG. II(iv) VERTICAL TIME SECTION - TRIVANDRUM (4 JUNE TO 12 JUNE 1968)

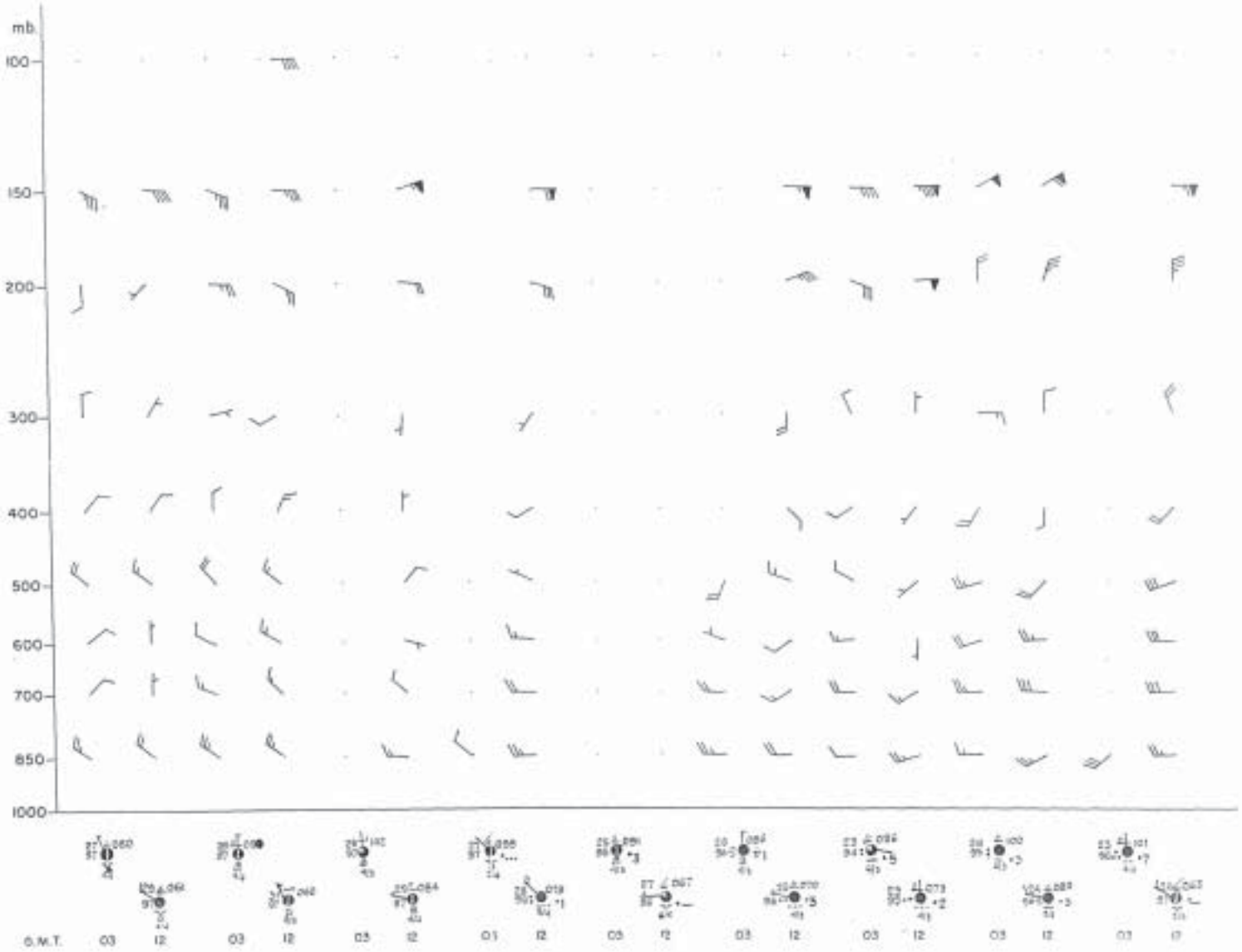


FIG. II(v) VERTICAL CROSS-SECTION ACROSS INDIA