UPPER AIR CHANGES OVER INDIA AND NEIGHBOURHOOD ASSOCIATED WITH THE SOUTH-WEST MONSOON

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As is well known, by far the most important feature of Indian weather is the south-west monsoon on which the agricultural economy of the country is so vitally dependent. The monsoon "bursts" over the Malabar coast by about the end of May, establishes itself over the whole country by the end of June and holds sway over the country for the next three months. The monsoon begins to weaken and retreat by the end of September. By the middle of October the south-west monsoon withdraws from the whole of North India and the central parts of the country; the pattern of circulation associated with the south-west monsoon undergoes a reversal and gives place to the north-east monsoon which brings rain to the eastern parts of south peninsular India during the months October to December. Figures 1 and 2 show the normal dates of onset and withdrawal of the monsoon over different parts of the country.

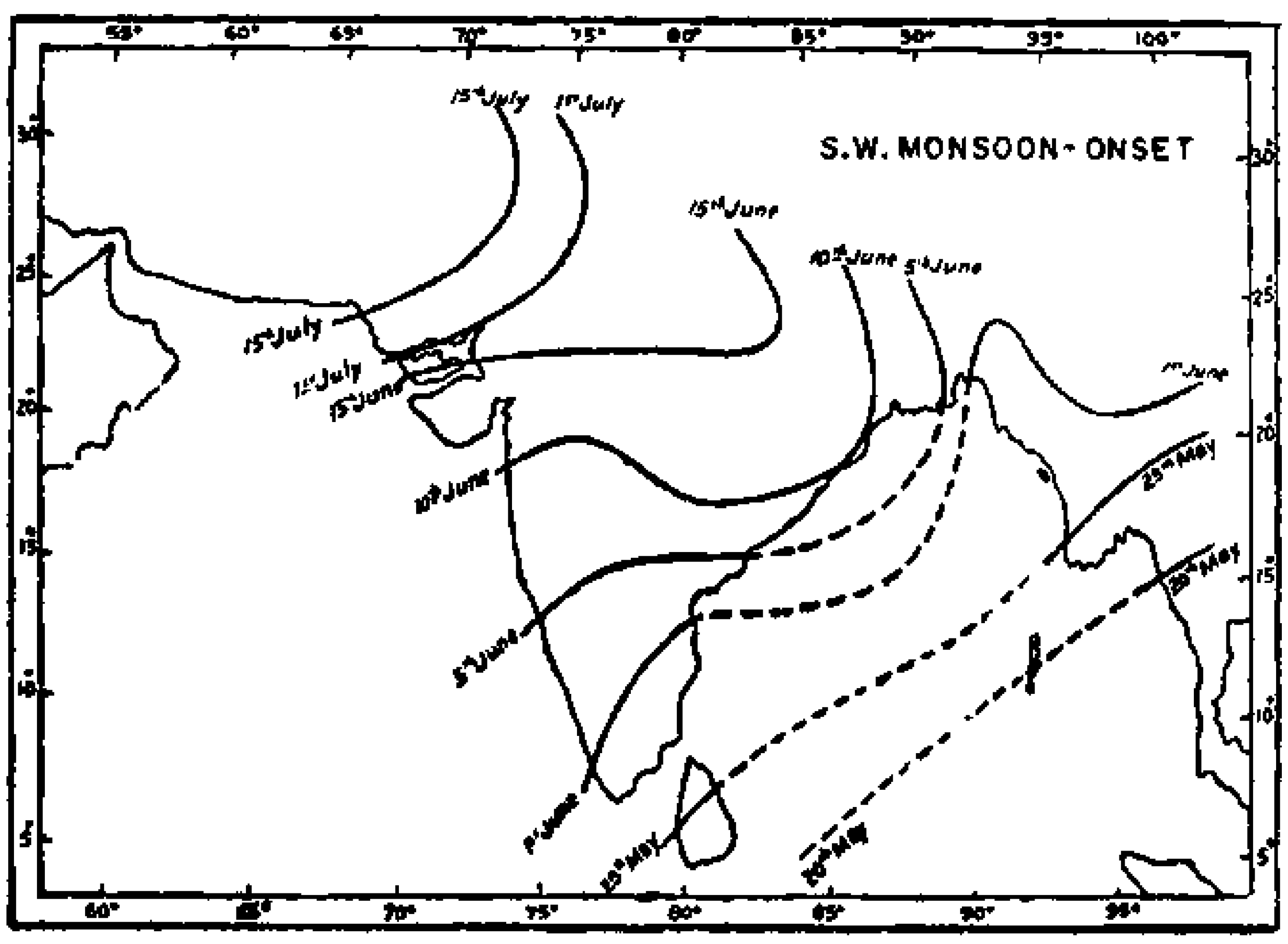

FIG. 1

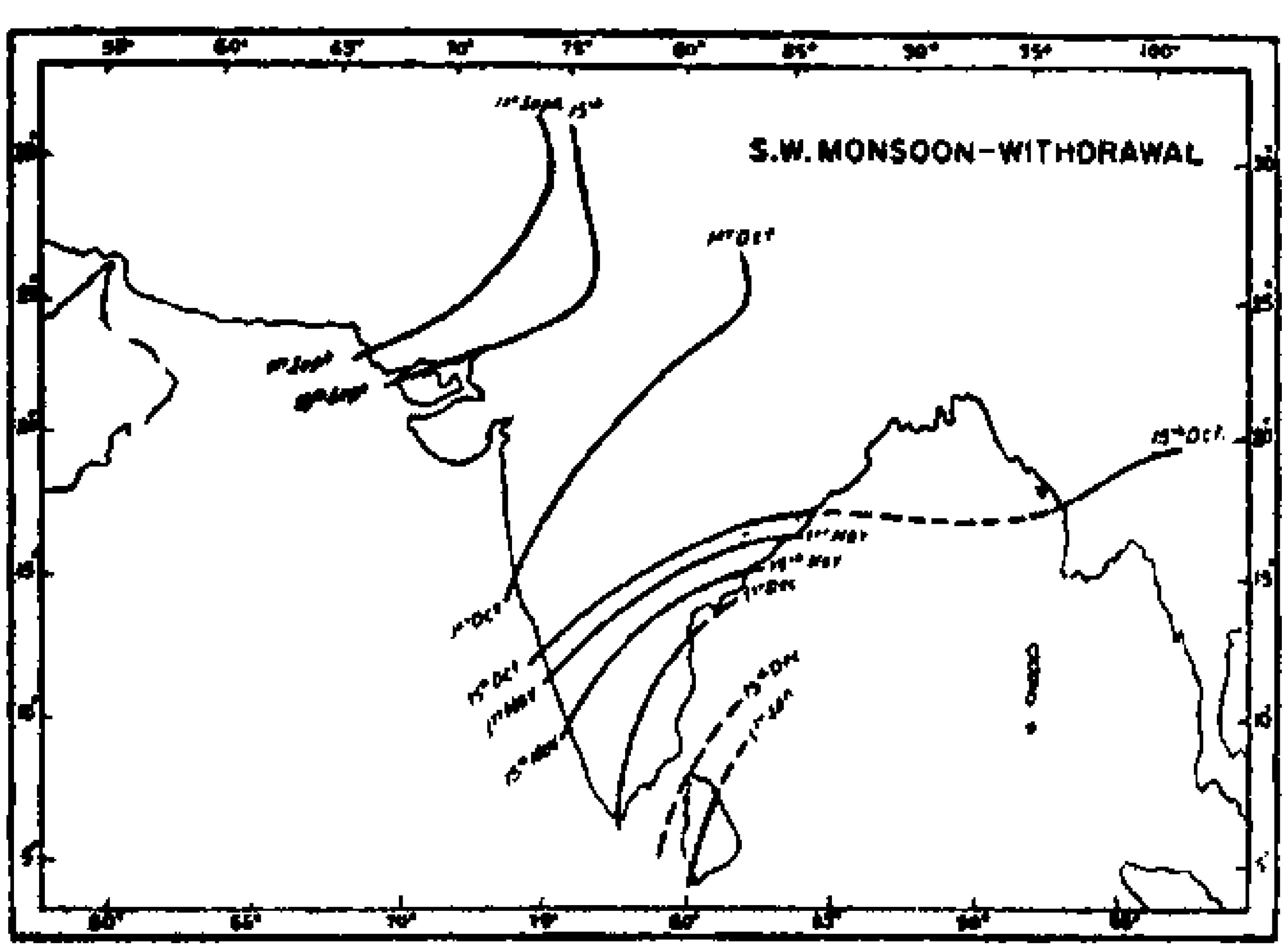

FIG. 2

2. In an interesting paper published in the Rossby Memorial Volume, Yeh Tu-Cheng, Dao Shih-Yen and Li Mei-Ts'un (1959) have drawn attention to the abrupt changes in the circulation over the northern hemisphere which they have noticed in June and October. Their conclusions are based on the study of the zonal winds from 850 to 200 mb. across five meridional sections—45°E, 90° E, 120° E, 165° E and 80° W —from the equator to latitude 50° N. In June they find a sudden northward shift of the westerlies and easterlies which heralds the establishment of the typical summer circulation. In October there is a sudden southward swing of the westerlies and easterlies which marks the beginning of the establishment of the typical winter circulation. The onset of the summer circulation is accompanied by the outburst of the south-west monsoon in India; the onset of the winter circulation signals the retreat of the monsoon. The Indian summer monsoon is thus seen to be an integral part of the general circulation of the northern hemisphere. The Chinese authors have put forth the interesting suggestion that so far as the upper atmospheric circulation is concerned there are only two natural seasons, namely a summer of short duration and a winter of considerably longer duration. The transitional periods are of brief duration and the transitions from summer to winter circulation and *vice versa* occur rather abruptly.

3. In connection with some work that we have recently undertaken we examined the seasonal variation of the mean monthly contour heights of standard isobaric surfaces at four radiosonde/rawin stations across India which lie approximately along a meridian. The stations considered are :—

		Latitude	Longitude
Trivandrum	..	08° 30′ N	76° 59′ E
Madras	..	13° 00′ N	80° 11′ E
Nagpur	..	21° 07′ N	79° 07′ E
New Delhi	..	28° 35′ N	77° 12′ E

For each of the standard isobaric levels 850, 700, 500, 300, 200, 150 and 100 mb. the mean monthly values of contour heights based on 1200Z radiosonde ascents for the five-year period 1956-60 were plotted on the same grid for the stations in question. The diagram thus obtained is shown in Fig. 3. In this diagram the mean monthly upper winds based on rawin ascents for each of the four stations are also depicted for the different levels. It should be mentioned that the wind data are based on averages for periods which are not quite homogeneous with the period for which the radiosonde data of contour heights relate.

other three curves reaching a maximum in November. The pressure gradient at the 850 mb. level (~ 1·5 km.) between Trivandrum–Madras–Nagpur gets reversed by about the end of April, Trivandrum pressure becoming higher than that of Madras and Nagpur. As

SEASONAL VARIATION OF CONTOUR HEIGHTS AND WINDS AT STANDARD ISOBARIC LEVELS ACROSS INDIA

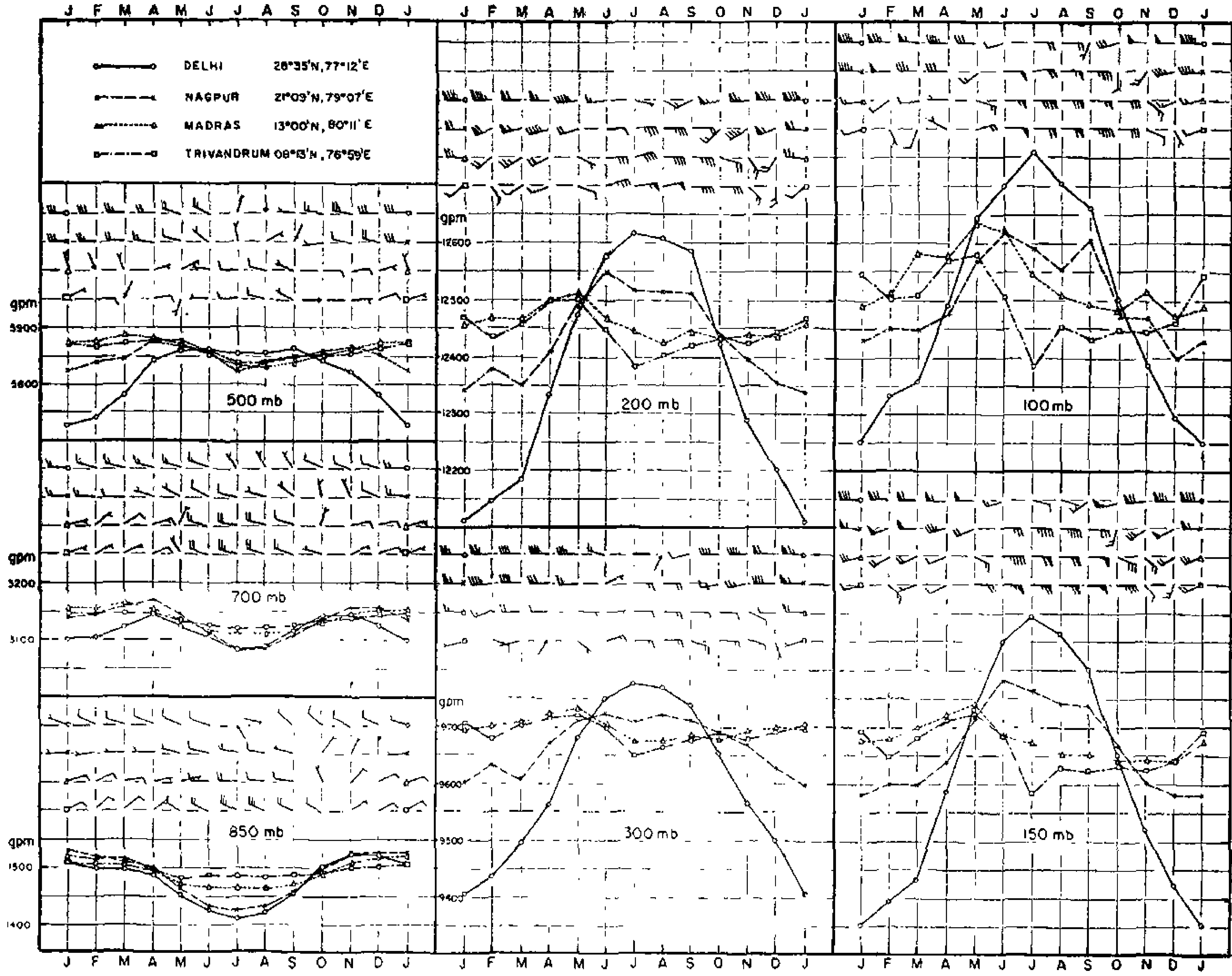

FIG. 3

4. An inspection of Fig. 3 brings out several interesting points some of which are the following :—

(*i*) The contour height of the 850 mb. surface at Delhi remains lower than that at the other three stations during all the months from January to October. From about the middle of April a steep and progressive fall sets in over Delhi and Nagpur reaching a minimum value in July after which the trend is again reversed. By about the end of September the Delhi curve overtakes the a consequence of this the ENE/NE winds at Trivandrum are replaced by WNW/NW winds in May which strengthen considerably with the steepening of the pressure gradient accompanying the onset of the monsoon.

(*ii*) At the 700 mb. level (~ 3 km.) the annual variation of pressure over Delhi and Nagpur shows two maxima, one in April and the other in November. The minimum at both places occurs in July. At this level the reversal of pressure gradient between Madras and

Trivandrum occurs in May and again in October. The pressure gradient between Delhi and Nagpur at 3 km. level is very feeble in the monsoon months.

(*iii*) At the 500 mb. (~ 6 km.) the Delhi curve overtakes the other three curves at the beginning of June. From June to September the pressure over Delhi remains higher than that over the three southern stations. By the end of September the Delhi curve again crosses the other three curves in the opposite direction. The July minimum in the Delhi curve is now very flat compared with the two lower levels. It is noteworthy that at the 500 mb. level the lowest value of contour height occurs over Nagpur in July. Pressure gradients across the country and hence the wind circulation are feeble at this level in the monsoon months.

(*iv*) The contour height curves and winds for the upper tropospheric levels bring out the remarkable changes that occur at these levels in association with the onset and retreat of the south-west monsoon. The Delhi curve for all the four levels are nearly similar with a steep maximum in July. At 100 mb. level the Delhi curve overtakes the curves for the other stations by the *first week of May*. From May to July there is a progressive fall of pressure over Trivandrum at 100 mb. level (~ 16·5 km.) while the pressure over Delhi is rising. The gradient across the country is thus progressively built up reaching a maximum by the middle of July which is the peak of the monsoon season. The easterlies over Madras and Nagpur at 100 mb. level reach their maximum strength in July.

(*v*) At 150 mb. level (~ 14 km.) the Delhi curve overtakes the curves for the other three stations by the *second week of May* resulting in the reversal of the pressure gradient across the country at this level. At 200 mb. level (~ 12 km.) the Delhi curve overtakes the other curves in the *third week of May* while at 300 mb. level (~ 9 km.) the crossing takes place in the *last week of May*. As already mentioned, at 500 mb. level the Delhi curve overtakes the other curves in the *first week of June*.

(*vi*) Thus starting from the 100 mb. level towards the end of April and working progressively downwards, the pressure gradients at all the upper tropospheric levels across the country get reversed by the end of May. The reversal of the pressure gradients in the upper troposphere brings about a complete reversal in the circulation and signals the burst of the south-west monsoon. The reversal of circulation in the upper troposphere is very well brought out by the winds plotted on the 200, 150 and 100 mb. contour diagrams.

(*vii*) The contour diagrams for all the levels show that the peak of monsoon activity is reached by the middle of July.

(*viii*) From the end of September a reverse sequence of events takes place. The contour height curve for Delhi crosses the other three curves by the end of September or the beginning of October at 500 and 300 mb. by the middle of October at 200 and 150 mb. and by the end of October at 100 mb. The monsoon or summer circulation in the upper troposphere completely changes over to the winter circulation by the end of October.

(*ix*) Thus May and October are the transitional months during which the winter type of circulation changes over to summer type and *vice versa*. The transition from the winter to summer circulation builds upwards in the lower troposphere and downwards in the upper troposphere. The sequence of events appears to proceed in the opposite direction in the upper troposphere for the change-over of the summer to the winter circulation.

(*x*) It is interesting to note that preceding the onset of the monsoon the curves for the upper tropospheric levels of 300, 200 and 150 mb. in Fig. 3 cross nearly at a common time epoch which varies systematically from level to level. This would account for the rather abrupt nature of the transition associated with the onset of the monsoon popularly known as the "burst" of the monsoon. The reverse transition is similar but not identical in its abruptness to the onset.

5. In an interesting paper entitled "Seasonal Changes in Upper-Air Conditions in the Mediterranean—Middle East Area" Sutcliffe and

Bannon (1954) have drawn attention to an association between the upper air-changes near the tropopause over the Middle East and the onset of the Indian summer monsoon. Table I gives the dates of onset of monsoon on the Malabar coast in the years 1948 to 1953 with associated upper tropospheric changes observed over Aden (Lat. 12° 49′ N, Long. 45° 02′ E), Bahrein (Lat. 26° 16′ N, Long. 50° 37′ E) and Habbaniya (Lat. 33° 22′ N, Long. 43° 34′ E).

TABLE I

	1948	1949	1950	1951	1952	1953
1 First appearance of easterly winds over Aden at 200 mb. ..	..	May 18	May 19	May 25	May 12	May 22
2 End of Polar type tropopause over Habbaniya ..	June 9	May 27	May 22	May 26	June 1	June 11
3 Onset of SW monsoon on Malabar coast ..	June 10	May 23	May 27	May 31	May 28	June 7
4 First appearance of easterlies over Bahrein at 200 mb. ..	June 15	June 13	June 10	June 13	June 8	June 20

It will be seen that the appearance of the easterlies over Aden precedes the onset of the monsoon by one to two weeks An inspection of Fig. 3 shows that in respect of the South Indian stations Trivandrum and Madras also, the easterlies get established in the upper troposphere before the onset of the monsoon, the mean winds for the month of May being easterly at all the upper tropospheric levels.

6. Examination of contour heights of standard isobaric levels in respect of Aden and Bahrein based on averages for the period 1948-50 shows that preceding the onset of the Indian southwest monsoon the reversal of pressure gradient between Aden and Bahrein takes place in the upper tropospheric levels at nearly the same epochs at which the reversal of the gradient between Madras and Delhi takes place over the Indian region

7. Our study shows that there is great similarity between the upper tropospheric changes over the Middle-east stations and over the Indian region preceding the onset of the Indian summer monsoon. As Sutcliffe and Bannon have pointed out, a careful study of these changes may have prediction value. We are making a detailed study of the upper air conditions over India and neighbourhood for the seven years 1955-61. Preliminary examination shows that the early onset of the monsoon in 1956, the late onset and early withdrawal of the monsoon in 1957 and the good monsoon activity in 1961 are all reflected in the contour diagrams for the upper tropospheric levels. Fuller details of our work will be published in the *Indian Journal of Meteorology and Geophysics*.

1. Yeh Tu Cheng, Dao Shin-Yen and Li Mei-Ts'un, *The Atmosphere and the Sea in Motion* (Rossby Memorial Volume), Oxford Uni. Press, 1959, pp. 249–67
2. Sutcliffe, R. C. and Bannon, J. K., *Sci. Proc. Int. Association of Met.*, Rome 1954, pp. 322–34.

ULTRASONIC ATOMIZATION OF LIQUIDS

WHEN a beam of ultrasonic sound of sufficient intensity is passed through a liquid and directed at an air interface, atomization of the liquid occurs. Liquid particles are ejected from the surface into the surrounding air, and under proper conditions very fine dense fogs may be produced. Unlike pneumatic atomization, the ultrasonic atomization has this advantage that the fog particle size and fog density can be independently controlled.

It has been suggested that capillary surface waves play a role in the atomization mechanism. This has been found to be the case according to R. J. Lang who reports the results of an experimental study on ultrasonic atomization [*Jour. Acoust. Soc. Amer.*, 1962, 34 (1), 6]. He finds that a definite relationship exists between the capillary wavelength at a given frequency and the size of the particles produced. Frequency range from 10 to 800 kc was used in the experiment and surface disturbances were studied by photographic method. Special methods were employed to measure the particle size.

It was found that uniform crossed patterns of capillary waves were formed on the liquid surface when atomization occurred. The diameter of the particles produced was found to be a constant fraction, 0·34, of the capillary wave-length.