RECORD DISCHARGE AND SEVERE FLOODS IN THE GODAVARI

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ABSTRACT

The Godavari experienced exceptionally heavy discharge and severe floods in August 1953. The basic synoptic mechanism which caused these developments has been pointed out. The feasibility of prognosticating the heavy rainfall which could cause such record discharge and severe floods has been discussed.

1. INTRODUCTION

THE Godavari is the largest river in peninsular India, its catchment covering an area of 30900 sq. kms. The river rises near Nasik in Maharashtra and after flowing eastwards or eastsoutheastwards for about 1460 kms, joins the Bay of Bengal in Andhra Pradesh. A diagram showing the basin may be seen in Fig. 1.

The record discharge occurred on 16 August 1953 at Dowlaishwaram and it amounted to 77900 cumecs (cubic metres per second). *This figure is higher than the discharge of* 72500 *cumecs in the mighty Brahmaputra in August* 1962[1], *the highest recorded in that river at Gauhati* (*Pandu*) between 1955 and 1970.

Rao[2] has very recently published in his book a list of heavy floods in India which had occurred in the last few decades. According to him, the highest recorded flood-level in the Godavari at Dowlaishwaram was 17·75 metres on 16 August 1953. This flood-level was 1·06 metres higher than the level for the Warning Stage above the Anicut at that gauging station. Besides other damage caused by it, the Godavari also overflowed its previous record at the Rajahmundry railway bridge.

These facts show beyond doubt that the case which we are now studying is of extraordinary interest.

Extracts from the hydrological information relating to the August 1953 floods as given in the UNESCO catalogue[3] are reproduced in Table I.

It would appear from a comparison of the figure 120 hours (*i.e.*, 5 days) given under (4) in Table I with the date 16.8.1953 given under (2) in the same table, that the water in the Godavari at the gauging site at Dowlaishwaram must have reached the flood-level for the first time on 11.8.1953 and that the peak-discharge was recorded 5 days later, *i.e.*, on 16.8.1953. The figure given under (3) suggests that the floods abated on or about 20 August, *i.e.*, after another 4 days.

2. AVAILABLE METEOROLOGICAL LITERATURE

The India Meteorological Department have published a Climatological Analysis of the rainfall variability over the Godavari basin. It however appears that a synoptic study has so far not been undertaken of floods in the Godavari. This may be partly because severe floods in this river do not occur frequently as they do, for instance, in the Himalayan rivers.

TABLE I

Peak Discharge (Cumecs)	Date	Total duration of flood (hours)	Time to peak hours	Maximum daily rainfall (mm)	Date	Hourly Maximum rainfall (mm)*	Date	Antecedent precipitation for	
								10 days	30 days
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
77900	16.8.53	216	120	28·7	13.8.53	29·2	12.8.53	151	408

* According to UNESCO, the maximum daily rainfall and the hourly maximum rainfall are given as mean values or representative values, valid for the whole basin. The hourly maximum rainfall would be based on the data of self-recording raingauges. The number of such self-recording instruments in any basin would naturally be small. The figure given for hourly maximum rainfall in Table I above may therefore be assumed to be only a representative value.

CATCHMENT OF THE GODAVARI & TRACKS OF DEPRESSION/CYCLONIC STORM

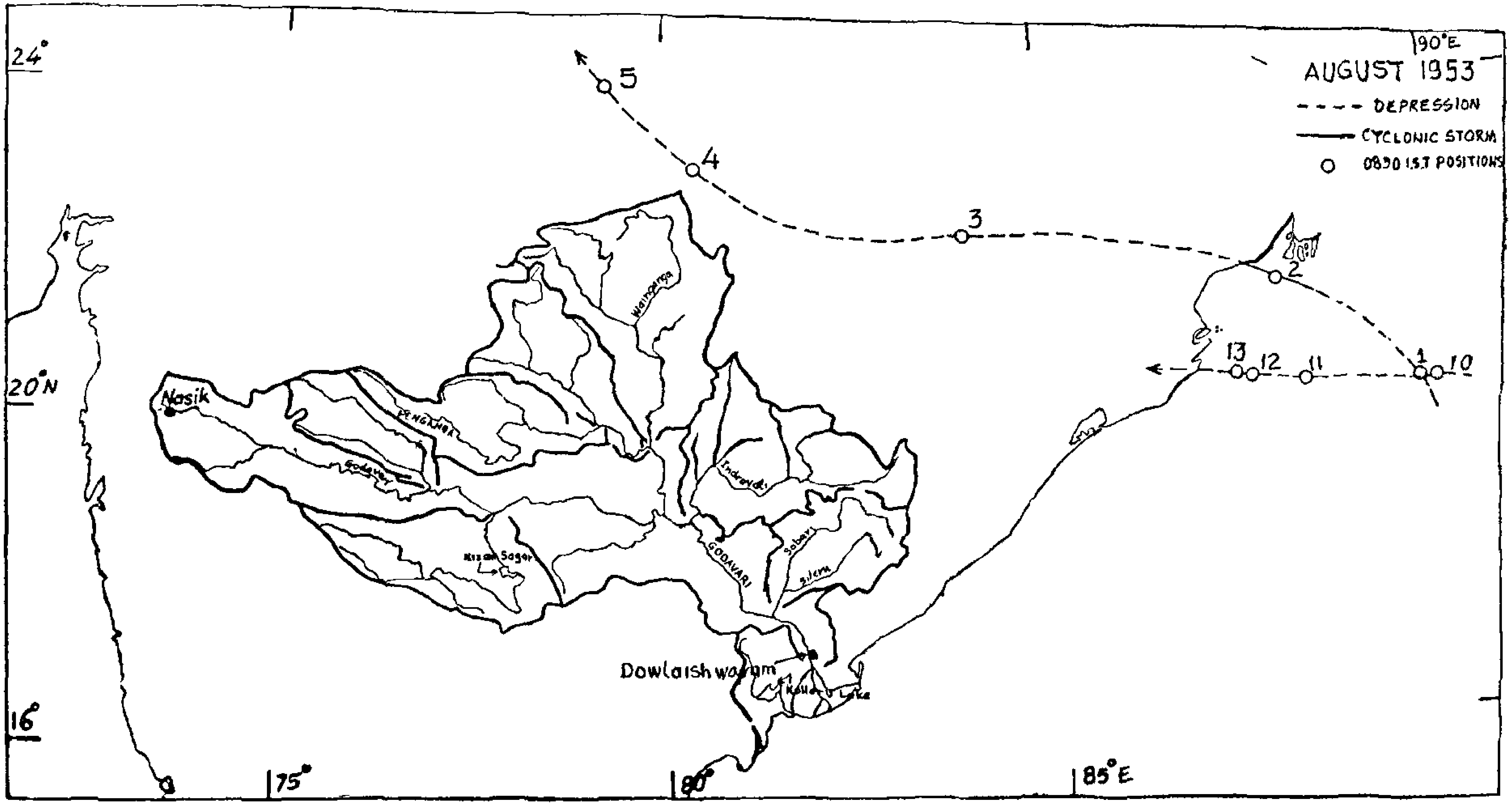

FIG. 1. Note that the depression of 10 to 13 August 1953 remained practically stationary on 12 and 13 and moved in a lower latitude than the depression/cyclonic storm of 1–5 August 1953.

Further, for a detailed study of the synoptic aspect, it is essential to have high level upper air data. These data have become available only recently. However, as the case we are presenting in this article is of exceptional interest, the authors have considered it worthwhile to study the same, by making use of the maximum available data.

3. Large-Scale Synoptic Situation

The floods were associated with two cyclonic systems, one following the other. The first system was deeper of the two. It initially developed as a depression in the Bay of Bengal on 1 August and intensified into a cyclonic storm of small extent at 0130 hrs. IST on the 2nd with its centre near 21° N, 88½° E. The pressure departure at this stage was 11 to 12 mb. The cyclonic storm moved slowly westnorthwestwards and at 0830 hrs IST was centred about 145 km southsouthwest of Calcutta. The pressure deficiency had increased by this time to 19 mb and the cyclonic circulation had extended at least upto 3·0 km. The cyclonic storm crossed the Orissa coast to the south of Balasore on the night of 2 August and at 0830 hrs IST of 3rd lay as a deep depression over Orissa with its centre near Sambalpur. It was centred on the morning of 4th about 130 km southeast of Jabalpur. Thereafter, it progressively weakened and moving northwestwards, lay as an extended trough over northwest Madhya Pradesh and adjoining east Rajasthan on the evening of 5th. The track of this cyclonic system as well as of the second one* referred to earlier, may be seen in Fig. 1.

The second cyclonic system developed into a depression on the morning of the 10th. In this case, the cyclonic circulation extended upto 3 km but the pressure-deficiency was distinctly less. The depression moved slightly westwards and was centred at 1730 hrs IST of 11th near 20° N, 88° E and at 0830 hrs IST of 12th near 20° N, 87½° E. The depression remained practically stationary till the morning of 13th. Later, it weakened into an elongated trough of low pressure extending from Sunderbans to the Orissa coast. It weakened further and passed inland across the Orissa coast during the course of 14th. It became unimportant on the 15th.

The upper winds and streamlines at 1430 hrs IST of 3 August and 12 August 1953 may be seen in Figs. 2 and 3 respectively. The 1430 hrs IST upper winds were preferred to the morning winds as more data were available at that synoptic hour. In regions where upper winds at 1430 hrs were not available, upper winds at 0700 hrs IST were plotted to facilitate the location of the centres more accurately. Even then, the error in our determination of the centres will not be less than half a degree of latitude and longitude.

4. Why did the Second Depression Remain Practically Stationary out in the Sea Close to the Coast on 12 and 13 August 1953 ?

It is not possible to give a fully satisfactory answer to this question in the absence of high level upper air data. However, the information available for the lower troposphere and sea level gives a plausible explanation for this development. Figure 4 shows the upper winds and streamlines at 1·0 km on the morning (0700 hrs IST) of the 13th. It will be seen that there is a pronounced ridge running from NNE to SSW at this level with its axis running from Bareilly (BRL) to Surat (SRT). The wind-flow to the east of the axis of the ridge is from NNW/N upto 20° N. And it had been more or less the same at 1430 hrs IST on 13th. The 998 mb sea level isobar at 0830 hrs IST on 13th had also an unusual configuration as it ran from Bareilly in the extreme north of west U.P. to Kakinada on the Andhra coast. The surface winds at 0830 hrs IST over East U.P. were *westerly* even at Varanasi. The 24 hrs pressure changes reported on 13th over the interior of Orissa and the central parts of the country were also diffuse. Further the easterly winds at 1·0 km along and near the Gangetic plain at 0700 hrs IST on the 13th were significantly weaker than on the 4th or 5th August in association with the first cyclonic system.

It is therefore not unreasonable to infer that the ridge had acted as a barrier obstructing the westward movement of the second depression and made it quasi-stationary out in the sea. The diffuse distribution of the 24 hrs pressure changes and the weakness of the easterlies along and near the Gangetic plain had probably also helped the persistence of the depression at the same location out in the sea. This explanation is supported by the fact that the wind-flow was westerly at 1·0 km even upto 22° N on the 15th (*i.e.*, after the depression had passed inland). The normal winds at this level as published by *I. Met. D.* are westerly at 0·9 km at 22° N and even further north.

5. Rainfall Analysis

A statement of district averages of rainfall in Madhya Pradesh and Maharashtra between 3 and 5 August 1953 as published in the India Weather Review

* The tracks of cyclonic storms and depressions published by I.Met.D.[5] do *not* show the positions of the second cyclonic system on 12 and 13 August, presumably because of the congestion caused by other tracks in that area. We have reproduced the tracks as published in I.Met.D.[6]

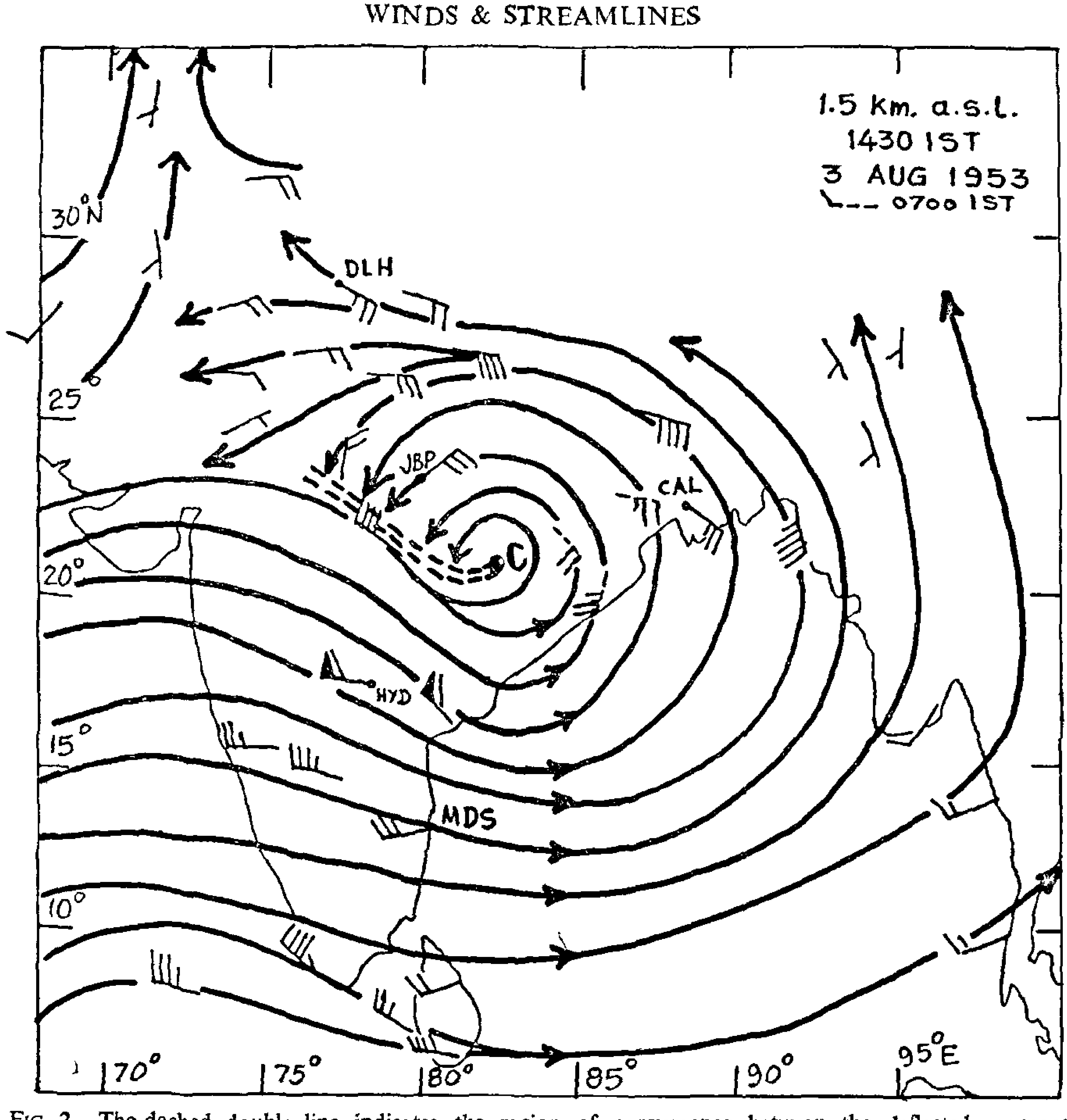

FIG. 2. The dashed double line indicates the region of convergence between the deflected monsoon northeasterlies and northerlies and fresh monsoon westerlies. C is the centre of the depression.

Annual Summary Part C, 1953 is given in Table II. Although some of the districts included in the Table cover portions of catchments of other rivers also like the Tapi (T) and the Narmada (N), the table contains valuable information in respect of very heavy rainfall in the catchment of the Godavari (G).

The heavy rainfall in association with the first cyclonic storm/depression between 3 and 5 August had occurred over the tributaries of the Godavari east of 78° E. The rainfall caused by the second depression between 12 and 14 August was less than that caused by the first cyclonic system. This was partly because the second depression was weaker than the previous one. It had also a much shorter track and had moved in a lower latitude (Fig. 1).

6. FORECASTING OF THE HEAVY RAINFALL

A comparison of Table II with the upper winds and streamline chart shown in Fig. 2 shows that the heaviest rainfall had occurred at quite a distance away from the centre of the depression. The heaviest rainfall had occurred on the area where the deflected monsoon northeasterlies and northerlies came in

WINDS & STREAMLINES

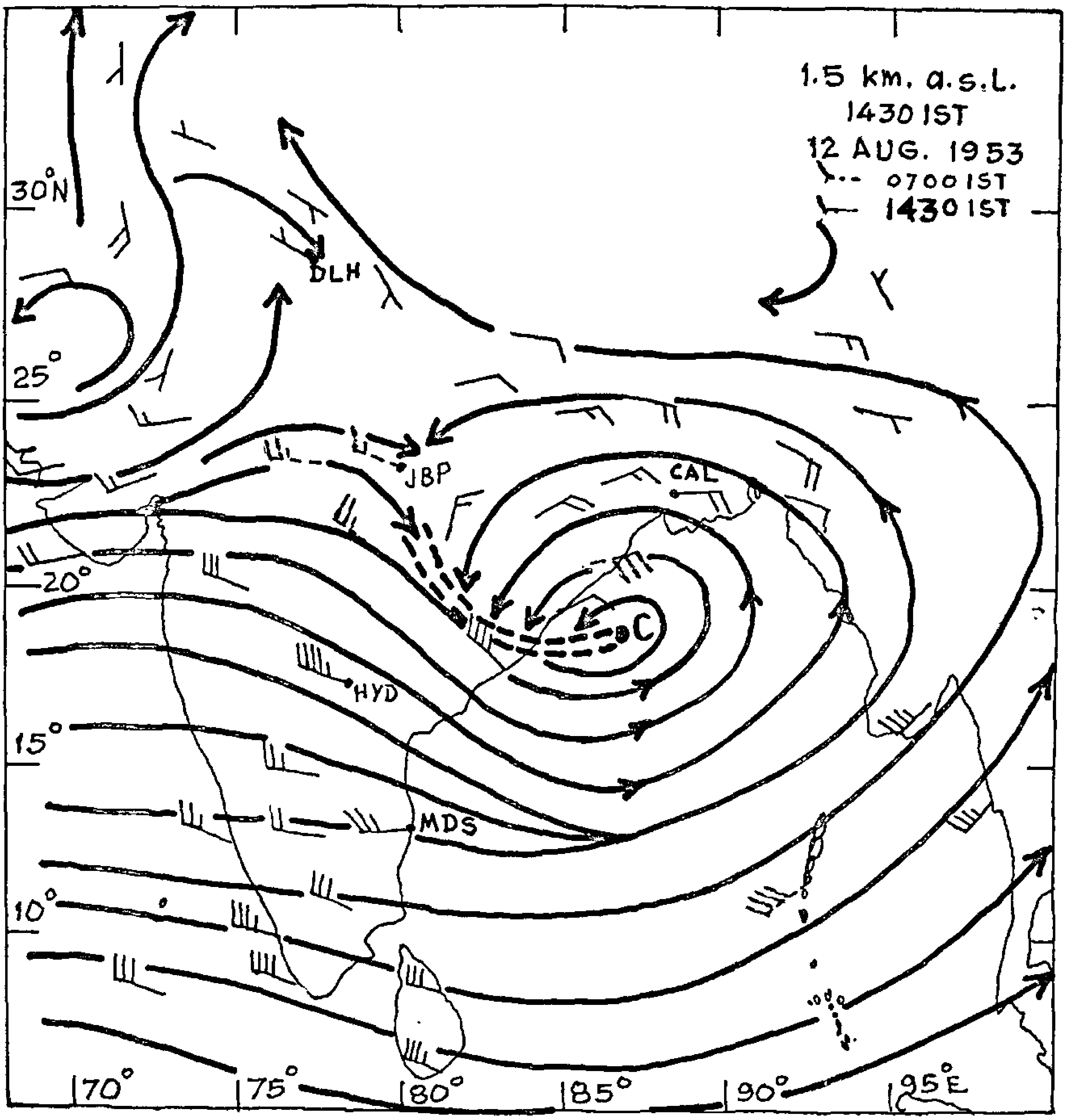

FIG. 3. Same as for Fig. 2.

TABLE II

District averages of rainfall (mm) in August 1953

State and District	3rd	4th	5th	State and District	3rd	4th	5th
Madhya Pradesh				*Maharashtra*			
Bastar (G)	46	117		Nagpur (G)		46	81
Chanda (G)	76	145	73	Wardha (G)		89	79
Bhandara (G)	25	86	122	Akola (T & G)		25	33
Balaghat (N & G)	33	46	84	Amraoti (T & G)		43	66
Betul (N, T & G)		102	102	Yeotmal (G)		40	48
Chindwara (N & G)		33	127				

N : Narmada; T ; Tapi; G ; Godavari.

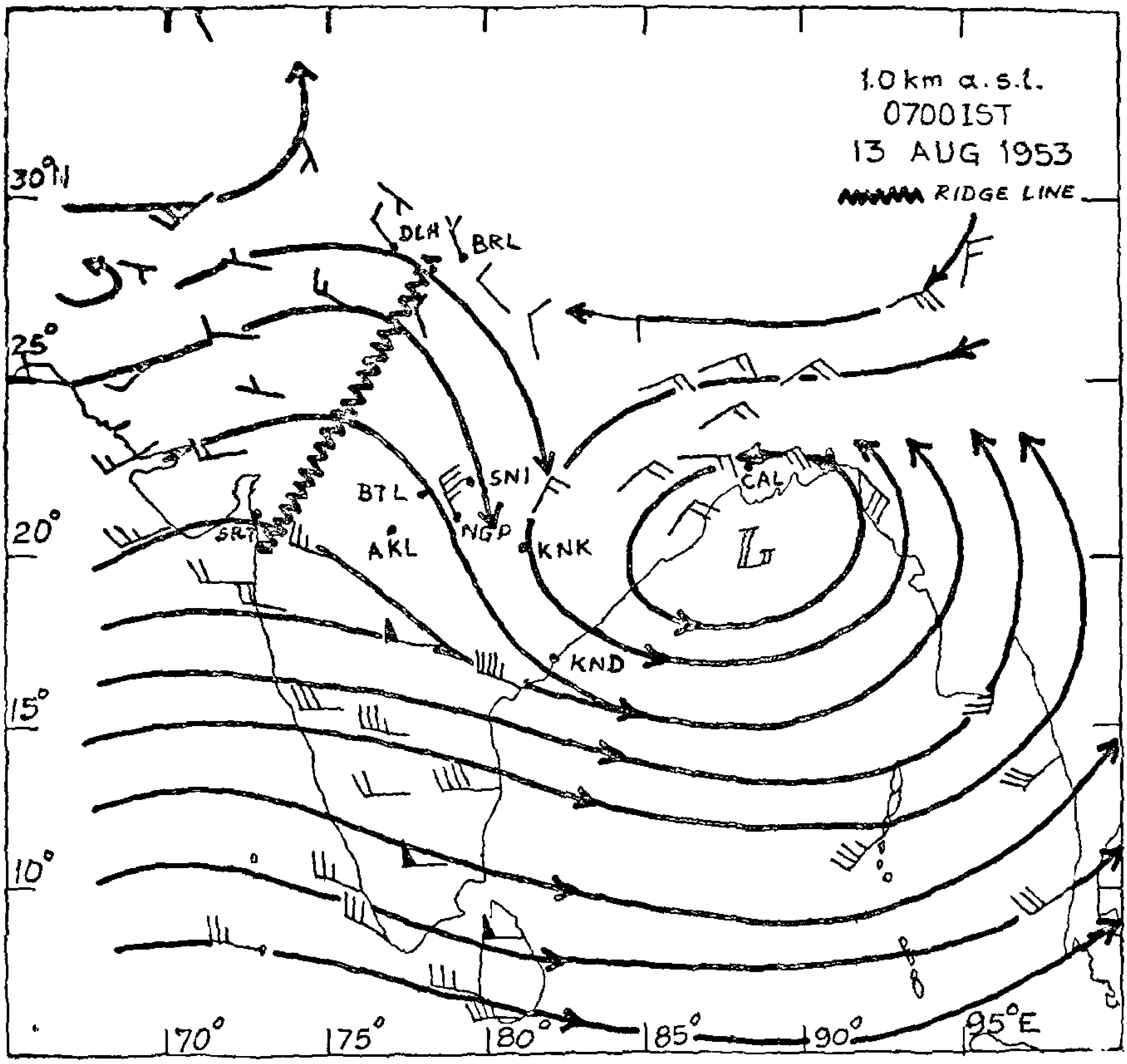

FIG. 4. L is the centre of the depression.

conflict with fresh monsoon westerlies. For instance, on 3 August, the centre of the depression was mid-way between Sambalpur and Raipur but the district averages of rainfall were quite heavy even in the upper reaches of the Tapi (T) and the Narmada (N) *to the north of the Godavari catchment*. This is also supported by a table which we have produced showing amounts of rainfall of 5" (127 mm) or more in 24 hrs ending at 0830 hrs IST on 4th and 5th, over the Godavari basin (Table not reproduced here).

The above analysis implies that if we are able to foresee the westward extension of deflected monsoon northeasterlies and northerlies sufficiently in advance, we should be able to foresee the development of very heavy rainfall at distant regions much earlier. On the basis of our findings, we are of the opinion that it should be possible to foresee earlier than we are doing at present, the westward extension of the deflected monsoon northeasterlies and northerlies and that, consequently, we should be able to issue *more timely heavy rainfall warnings for regions far* away from the centre of the monsoon depression. As our conclusion is however of a qualitative nature, it can be utilised *in routine operational practice* with sufficient confidence only by weather-analysts with a background of synoptic experience.

7. Isohyetal Analysis

Figure 5 shows the isohyetal pattern associated with 2-day maximum rainfall on 4 and 5 August.

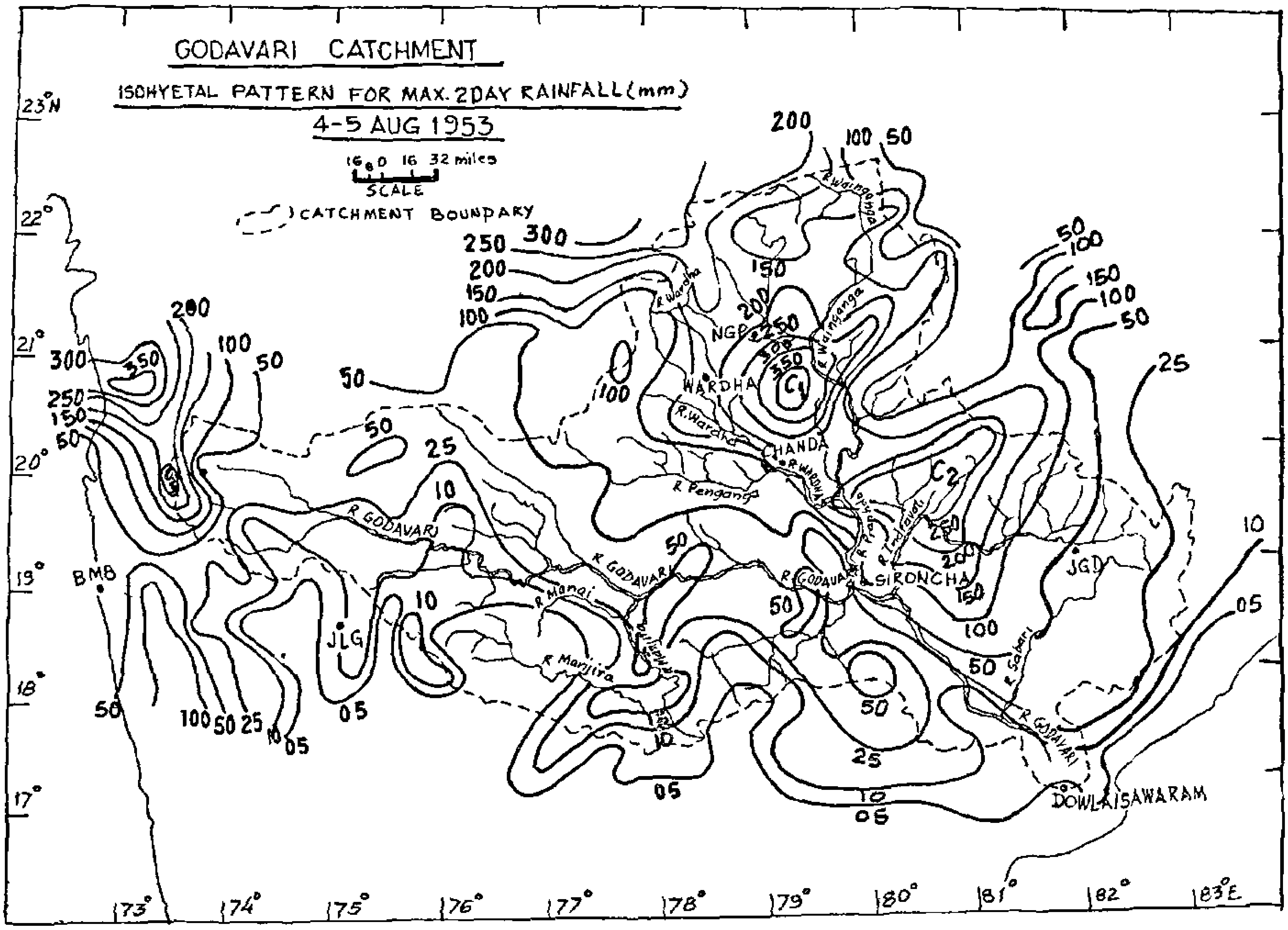

FIG. 5. Note the extensive areas in the rainstorms C_1 and C_2, in which the 2-day rainfall exceeded 150 mm.

The isohyetal pattern shows three centres of rainstorms over or near the Godavari catchment. For easy reference we have referred to these rainstorms as C_1, C_2 and C_3. These are briefly discussed below:

(*a*) C_1 is the most intense among these rainstorms. It must have caused very heavy rainfall over the Wainganga and the Wardha.

(*b*) C_2 must have caused very heavy rainfall over the Pranhita, the Indravati and its tributaries, and the lower reaches of the Wainganga.

(*c*) C_3 lies mainly *outside* the Godavari catchment and is associated with orographic and other effects connected with the Western Ghats. It will also be noted that rainfall decreased rapidly to the east towards Nasik wherefrom the Godavari rises. C_3 would not have therefore caused any large increase in the water-level in the Godavari.

We have also made a rough isohyetal analysis of rainfall which occurred in association with the second cyclonic system referred to earlier. We have found that the main rainstorm-centre for 2-day maximum rainfall on 13 and 14 August lay over the region of confluence of the Pranhita and the Indravathi with the Godavari, *i.e.*, over the area centred near 19° N, 80° E (isohyetal pattern not reproduced here). The 2-day maximum point rainfall was 470 nm at Ahiri in the Chanda District in Maharashtra. This rainfall was about 120 mm *more than* the maximum point rainfall associated with the rainstorm C_1 in Fig. 5. It is also of interest to note that rainfall of 125 mm or more in the 2-day maximum occurred over the whole of the catchment of the Indravathi in association with the second cyclonic system.

8. Why Did Such an Exceptionally Heavy Discharge of 77900 Cumecs Occur at Dowlaishwaram on 16 August?

A precise answer to this question can be given only on the basis of discharge-hydrographs recorded at the different stages of the river and of a number of other factors. As these data are however not available to us, our answer is based on figures which give only an idea of the order of magnitude of the various parameters involved. Our broad explanation is given below:

(*a*) Abbi *et al.*[7] have shown that, in the case of the Narmada, the contribution from the farthest end of the basin reaches the Garudeshwar discharge site in about 6 days. The distance involved in this case is about 1000 kilometres[8]. In the case of the Godavari, the remotest point in the catchment east of 78° E is also about 1000 kilometres. Consequent on this, the heavy rainfall from the remotest point in association with the first cyclonic system would have also taken about 6 days.

(*b*) Other conditions remaining the same, the lag-time will be more when the mean slope of the river is less. In the case of the Narmada, the mean slope is 0·054[3], while in the case of the Godavari is 0·046. Hence the lag-time would be more in the case of the Godavari than in the case of the Narmada.

(*c*) Assuming that other conditions remain identical, the larger the area of the catchment, the greater will be the lag-time for the flood-waters from the area of heavy rainfall to reach the gauging station. In the case of the Godavari catchment east of 78° E, the area of heavy rainfall is double if not more than that of the entire Narmada basin discussed by Abbi *et al.*

(*d*) The centre of the rain-storm associated with the 2-day maximum rainfall on 13 and 14 August was about 300 kilometres (crow-fly distance) from the Dowlaishwaram guaging site. On the basis of what we have stated in (*a*) above, we would not be wrong in inferring that the flood-waters from this rainstorm-centre (13–14 August) would have taken 2 to 3 days to reach Dowlaishwaram. In other words, they would have reached the gauging station near about the same time as the flood-waters associated with the first cyclonic system.

Thus we see that the nearly simultaneous arrival of the flood-waters associated with the two different cyclonic systems, resulted in the phenomenal discharge of 77900 cumecs on 16 August 1953 *vide* Table I.

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