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Weather in relation to the floods in Bihar, Bengal and Assam during July and August 1954

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The recent floods in the rivers Gandak, Kosi and Brahmaputra and their tributaries during July and August 1954 have received serious consideration in Government circles as well as from the public. According to the statements in the press, these floods in Bihar, Bengal and Assam had taken a toll of 247 lives. " A total area of 25,650 square miles and nearly 95 lakhs of people have been affected and a large number of cattle-heads have perished. Serious damage to crops, roads, railways and bridges has also occurred on a scale never experienced before ". According to newspaper reports the floods of this year are unparalleled within living memory. The most severe flood in the Kosi within living memory occurred in 1927. The maximum discharge during that flood has been estimated between 600,000 and 700,000 cusecs (CWINC, 1950). But this year, the estimated discharge of Kosi on 26 July was 625,000 cusecs, nearly the same as in the 1927 flood ; in the last week of August also a discharge of the same order was recorded.

Curiously enough, while north Bihar, north Bengal and Assam were writhing under the impact of floods, the southern districts of U.P., south Bihar and Orissa were having a partial drought. These floods have, therefore, been entirely due to the rains in the Himalayan catchments of the rivers concerned. One is led to wonder what has been the character of the rains in the Himalayan region which were responsible for the floods of such stupendous magnitude and what special meteorological features were prevalent during July and August of this year which caused the intense rains in the Eastern Himalayas.

Regarding the first question, *viz.*, the actual intensity and distribution of rain in the various hill catchments in the Himalayas, unfortunately, definite answers cannot be found, as most of these catchments do not have any rain recording stations in them. The catchments concerned are those of the Gandak, the Kosi and the Brahmaputra and their tributaries. Of these, only in the Kosi catchment in Nepal, rain recording stations have been functioning for the last few years ; for the others, no rainfall data are available. Fig. 1 shows the network of observatories in the Kosi catchment.

The analysis of the data from the stations in the Kosi catchment for the years 1948-52, together with the associated synoptic situation has shown, among other things, that heavy rainfall in the catchment is almost always associated with ' break ' conditions in the monsoon, during the period June to September (IMD, 1954). This conclusion can also be taken to apply to the other catchments in the Eastern Himalayas.

Southwest monsoon season and 'breaks' in the monsoon

The normal isobaric and wind conditions over India during the southwest monsoon, though well known, are briefly described here. A closed ' low ' pressure area lies over the region Baluchistan, Sind and neighbourhood and an elongated trough extends from there to the northwest angle of the Bay of Bengal. The axis of the trough on a day of normal monsoon runs approximately from Ganganagar to Sandheads through Agra and Daltonganj. South of the axis, the winds are westerly and north of it, in the Gangetic basin they are easterlies. In the higher

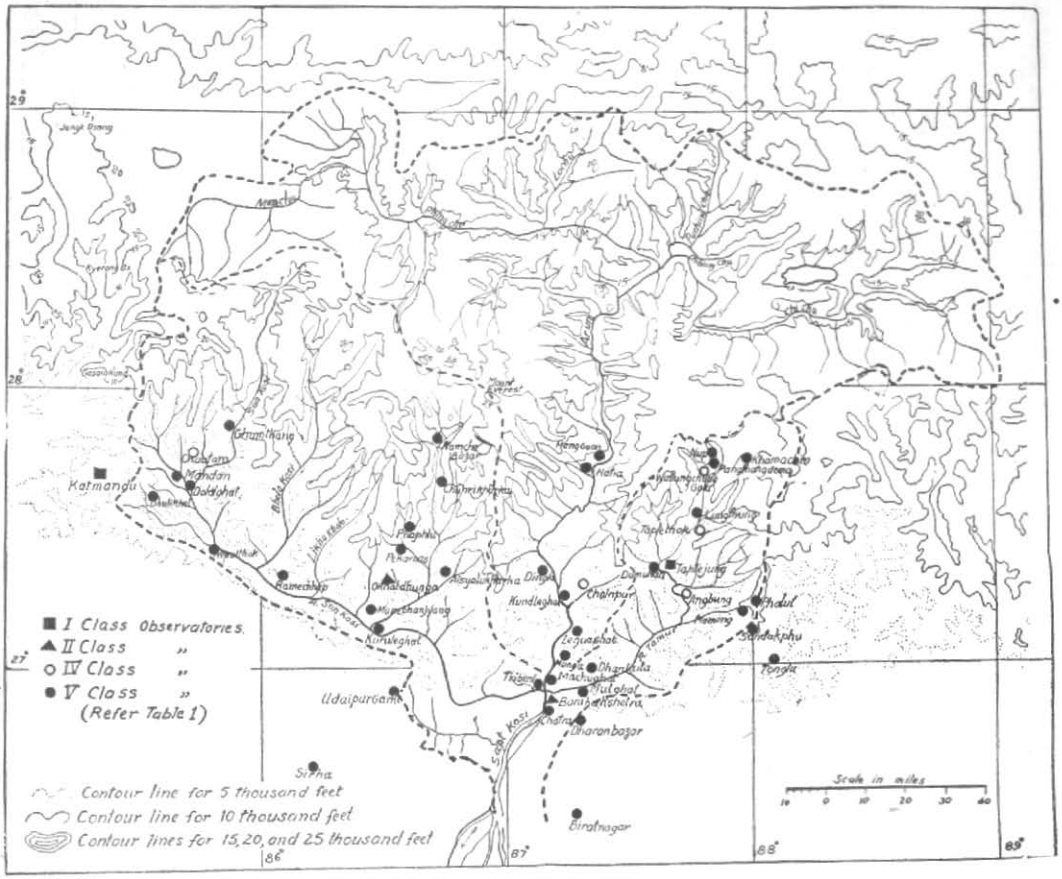

Fig. 1.

levels also, this type of wind circulation exists, with a discontinuity line between the westerlies to its south and the easterlies to the north. In the region of West Pakistan and West Rajasthan, the wind circulating round the ' low ' over that area is on most days dry and hot tropical continental air. With the axis in its normal position and the monsoon active, well distributed rain occurs in the Gangetic plains and only moderate rain in the hills (see Fig. 2). Periodically, depressions form in the northwest angle of the Bay due to the advent of waves in the easterlies into that area, and these depressions move along the monsoon trough westnorth-westwards intensifying the rain in that region. The distribution of rain is determined by the position of the axis which is often oscillating about its normal position, and the strength of the monsoon streams. It, sometimes, happens that the axis shifts north to the foot of the Himalayas. When this happens, the monsoon trough will be absent on the Indian chart (see Fig. 3), the easterlies will disappear and the whole country will be over-run by westerlies. Such a situation is referred to as ' break ' in the monsoon. With the setting in of the ' break ', the rains decrease considerably in the interior of the country, but they continue along the west coast and increase in and near the Himalayas. The intensity of rain over and near the hills during a ' break ' depends upon the supply of monsoon air, *i.e.*, the strength of the Arabian Sea branch of the monsoon. Usually, ' breaks ' in July are short-lived. The advent

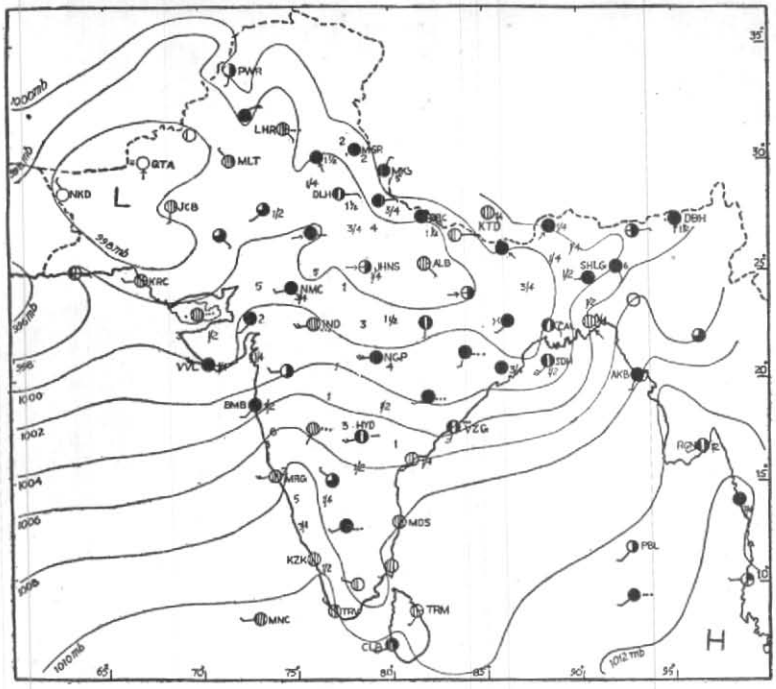

Fig. 2. Weather Map for 0830 IST on 11 July 1954

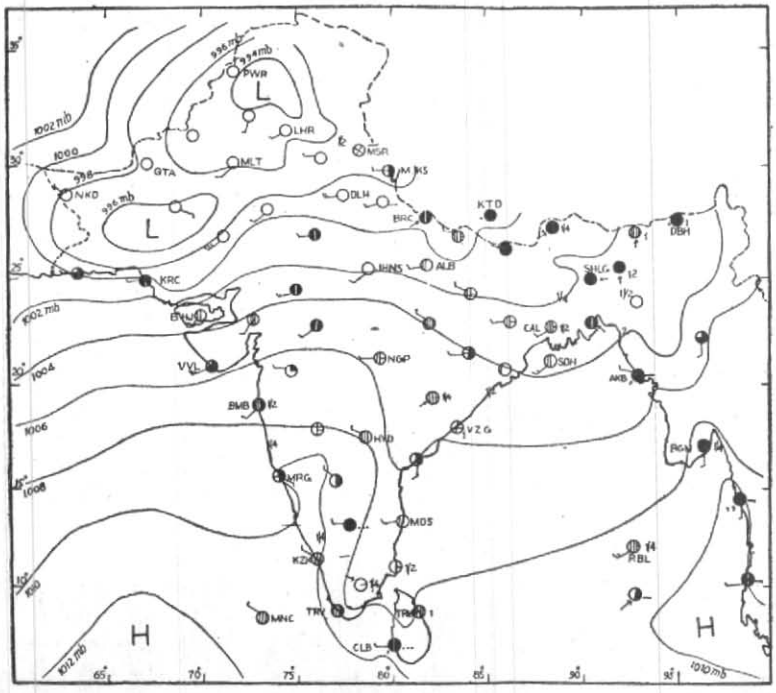

Fig. 3. Weather Map for 0830 IST on 24 August 1954

of an easterly wave in the north Bay revives the easterlies in the Gangetic valley, thus restoring the trough and pushing the axis to its normal position. Even if a 'break' persists longer, the monsoon usually weakens and the rains in the hills decrease considerably after the first few days.

Weather of July 1954

The monsoon was following its normal course and had progressively extended over the whole country by the middle of July aided by two depressions from the Bay of Bengal and two from the Arabian Sea. A land depression which formed over Gangetic West Bengal on the 14th morning moved into southeast Rajasthan on the 16th and weakened there by the 18th. In its association, strong monsoon conditions generally prevailed over northeast India and heavy rains also occurred over south Madhya Bharat, north Deccan and south Madhya Pradesh. With the weakening of the depression over Rajasthan and the simultaneous movement of a westerly wave eastward across the Punjab hills, locally heavy to very heavy rain occurred in north Punjab (I) on the 18th on which day Pathankot recorded 7″. The heavy rainfall belt shifted to northwest Uttar Pradesh by the 20th when Dehra Dun reported 10″ and Nainital 5″. These heavy rains caused floods in the river Ravi. As the westerly wave moved across the Eastern Himalayas between 18th and 19th, it pulled up the Bay monsoon air to the Eastern Himalayas where copious rain must have fallen. On the 19th, Cheerapunji recorded 17″ of rain, Cooch Behar 4″ and Jalpaiguri and Siliguri 3″ each.

After the 19th, the axis of the monsoon trough shifted to the foot of the Himalayas and the 'break' conditions thus brought in prevailed practically till 29 July. During this period the Arabian Sea branch of the monsoon which was speeding up to the hills continued to be strong so that the rain in the Eastern Himalayas due to the westerly sweep was heavy. The orographic effect was augmented by the movement of three low pressure waves eastwards across the Nepal Himalayas. Moreover, a wave in the easterlies moving across the Central Bay of Bengal between the 23rd and 24th strengthened the monsoon over that area. This, combined with the passage of the westerly wave eastward across the Nepal Himalayas, gave rise to a well marked wind discontinuity extending from the West Central Bay of Bengal northwards through Cuttack and Raipur, Allahabad, Gorakhpur and further to the hills on the 23rd. Southerly winds to the east of the discontinuity carried the fresh monsoon air from the Bay of Bengal to the Eastern Himalayas. The active convergence of the monsoon air from the Bay of Bengal and from the Arabian Sea on the Eastern Himalayas was maintained for the next 5 days (24th-28th) by the movement of another westerly wave from the Punjab (I) across the Eastern Himalayas to Assam between the 24th and 28th and heavy to very heavy rain occurred in north Bihar, Sub-Himalayan West Bengal and Upper Assam during this period. Rainfall in the Eastern Himalayas also should have been excessive during the same period. Katmandu recorded 7″ of rain for the 24 hrs ending at 0830 IST of 27 July and another 4″ during the next 24 hours. 7″ in 24 hours is a record rainfall for Katmandu. Another westerly wave moved into the Punjab (I) on the 27th. During its passage across the Eastern Himalayas moderate to heavy rain occurred there.

The daily rainfall at some stations in Nepal Himalayas and also for some stations in north Bihar, north Bengal and Upper Assam for the period 19-31 July are given in Table 1. To bring out the concentration of rain during the last ten days of July more clearly, the total rainfall of July 1954 is also given in the table. Spells of heavy rain are given in bold types. The last column contains the average July rainfall for all the stations. A glance at the table will show the concentrated nature of the rainfall in the Himalayan region during the period 24 to 28 July. This concentration was apparently responsible for the heavy floods of the last week of July in the Kosi and Gandak rivers in Bihar and the Brahmaputra in Assam.

After the 28th, conditions became unsettled in the north Bay of Bengal and adjoining areas and the trough started shifting south. The rains in the hills began to decrease thereafter. The chief features of the last 10 days of July when very heavy rains in concentrated spells occurred along the Eastern Himalayas can, therefore, be summarised thus :

(*i*) the existence of ' break ' conditions with the axis of the monsoon trough situated close to the foot of the Himalayas ;

(*ii*) movement of four active westerly waves in quick succession along the southern periphery of the Himalayas ;

(*iii*) a deep easterly wave with a closed cyclonic circulation which moved between the 23rd to 26th from the west central Bay of Bengal to northeast Arabian Sea across Hyderabad ;

(*iv*) the continued strength of the Arabian Sea branch of the monsoon throughout the period.

Of the above, feature number (*ii*) namely the westerly waves moving across the lower periphery of the Himalayas was a unique synoptic feature of this year's July. Also, feature (*iii*) was an unusual and important feature. As is well known, in normal years, the easterly waves in July move westnorthwestwards across the Gangetic valley ; the westerly waves are practically absent and, if they appear, they move across the Punjab hills and Kashmir. On the rare occasions when the westerly waves skirt the southern periphery of the Himalayas, the easterly waves completely disappear from the Indian region and, with them, the Bay branch of the monsoon also. In such cases the Arabian Sea branch of the monsoon remains active for a short period only, with a brief spell of heavy rain along the Eastern Himalayas. As outlined in the last para, conditions during this July were altogether different and hence the incidence of unusually concentrated rain in the hill catchments and the consequent very heavy floods.

It may be mentioned in passing, that a little before or about the same time as the floods in Bihar and Assam, severe floods have also been reported to have occurred in Iraq, Lower Tibet and South China. A meteorologically common feature of the latter two regions with North India is that they lie along the track of the westerly waves and in the monsoon regime. This may be an indication of the important part played by the westerly waves in this year's floods. In the absence of actual data, to expatiate more on this aspect will be idle speculation.

Weather conditions in August 1954

The monsoon was generally below its normal activity during the first half of August. The seasonal trough of low pressure became accentuated over the region extending from southeast Uttar Pradesh to the Punjab on the 15th and remained so, for the next four days. This was responsible for vigorous monsoon conditions in north Punjab (I) and northwest Uttar Pradesh on the 14th and 15th and active monsoon conditions over the rest of Uttar Pradesh and in Bihar from 15th to 18th. Thereafter, the axis of the monsoon trough shifted northwards and remained close to the foot of the Himalayas till the 25th, thus bringing in the ' break ' conditions in the monsoon. During this period (18th-25th), three westerly waves moved eastwards across the Punjab-Kumaon hills. The conditions during this week were thus similar to the conditions which existed over these areas during the last 10 days of July, with one difference, namely, the absence of an active easterly wave in the south and central Bay of Bengal. This absence was a blessing as, otherwise, the intensity of the rain and, therefore, of the floods in August could have been much more than what they actually were. During the ' break ' period in August, the monsoon was vigorous in and near the Punjab-Kumaon hills on the 19th and 20th, in north Bihar from 20th to 22nd and in northeast Assam during most of the days. Though the rainfall in the submontane plains was only moderate, in the hills, rainfall should have been very heavy. Katmandu recorded nearly 10" of rain during

TABLE

Daily rainfall (inches)

	19	20	21	22	23	24
HIMALAYAS NEPAL						
Katmandu ..	0·53	0·83	0·54	0·00	0·00	0·03
Chautara ..	0·78	0·84	0·90	0·13	0·07	0·54
Dolalghat ..	0·10	0·23	0·00	0·00	0·00	0·00
Dhulikhel ..	0·99	0·69	2·09	1·11	0·73	0·79
Gumthang ..	1·41	1·11	2·09	0·79	4·50	**6·74**
Machuaghat ..	0·00	0·79	0·20	0·56	0·25	0·73
Munga ..	0·30	2·25	0·50	1·64	1·25	**2·15**
Phalut ..	0·35	2·00	2·05	0·82	0·87	0·88
Tribeni ..	0·00	1·00	1·35	0·50	0·35	1·35
Barahakshetra ..	0·02	2·93	2·92	0·95	0·02	**5·38**
Chatra ..	0·15	1·97	1·82	0·87	0·13	**3·86**
Dharanbazar ..	3·30	5·00	2·00	2·30	3·00	**7·30**
Biratnagar ..	3·46	1·73	1·86	0·21	0·00	0·13
NORTH BIHAR						
Dharbanga ..	0·06	0·07	0·48	0·00	0·19	0·00
Motihari ..	2·05	0·00	2·04	..	..	0·00
Purnea ..	1·11	0·26	0·45	0·00	1·37	0·78
NORTH BENGAL						
Jalpaiguri ..	0·85	4·84	0·53	3·37	3·70	2·59
UPPER ASSAM						
Dibrugarh ..	0·45	0·33	0·09	0·26	1·68	**1·90**
Dhubri ..	3·70	0·00	2·87	4·03	0·00	**3·45**
Tura ..	1·95	0·18	0·82	0·70	0·36	**5·74**

TABLE

Daily rainfall (inches)

	19	20	21	22	23	24
HIMALAYAS NEPAL						
Katmandu ..	0·29	0·00	0·56	0·13	**1·97**	**2·20**
Dolalghat ..	0·00	0·00	0·04	**1·80**	**2·10**	**2·17**
Dhulikhel ..	0·35	0·05	0·03	0·65	**1·51**	**4·30**
Gumthang ..	1·90	1·55	1·61	1·97	0·97	0·95
Machuaghat ..	0·17	0·05	0·00	0·69	0·56	**5·06**
Phalut ..	0·55	0·67	0·45	0·37	**1·90**	**4·36**
Tribeni ..	0·25	0·19	0·00	**2·15**	**1·40**	**4·50**
Barahakshetra ..	0·19	0·13	Tr.	**2·82**	**2·83**	**4·91**
Dharanbazar ..	0·09	0·15	0·00	0·20	**1·30**	**2·30**
Biratnagar ..	1·43	0·04	0·25	0·28	0·05	0·00
NORTH BIHAR						
Dharbanga ..	0·54	0·93	0·68	3·00	0·00	0·00
Purnea ..	0·30	0·02	0·11	1·60	0·25	0·00
Motihari ..	0·46	1·48	..	3·35	0·00	0·00
UPPER ASSAM						
Dibrugarh ..	0·76	1·31	1·07	1·01	0·61	**1·04**
Dhubri ..	0·00	0·00	1·70	0·00	0·20	0·39
Tura ..	0·03	0·03	1·48	4·65	0·61	0·00

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for 19—31 July 1954

25	26	27	28	29	30	31	Total for July	Mean monthly rainfall
0·13	1·39	6·82	3·74	1·15	0·00	0·06	21·93	14·32
2·80	3·90	1·95	0·71	0·00	0·07	0·08	21·81	19·48
3·15	1·20	0·24	2·00	0·00	0·20	0·14	7·49	12·40
0·68	5·71	6·95	4·91	0·00	0·10	0·00	33·77	15·11
5·95	4·59	6·97	7·19	6·45	2·65	0·92	107·16	36·52
6·60	4·35	1·70	2·13	1·70	0·41	0·00	24·00	10·57
2·27	1·12	1·76	0·52	0·00	0·00	0·00	16·47	11·52
3·80	4·20	1·25	1·45	0·34	0·73	1·22	33·20	21·23
6·50	5·75	1·28	2·35	1·50	2·22	1·05	29·52	14·12
6·74	6·09	1·21	3·18	2·46	1·76	4·74	43·31	20·98
6·18	6·60	2·42	5·57	2·27	2·18	5·65	47·81	18·27
6·20	3·40	3·20	5·50	0·30	5·30	6·50	58·36	19·76
3·51	2·58	0·45	4·48	0·00	0·46	0·91	29·25	18·85
0·71	1·92	1·76	2·76	0·55	0·00	0·23	13·00	12·12
0·66	3·00	0·14	2·13	0·45	0·00	0·00	13·60	15·00
0·93	1·30	0·38	3·55	0·10	0·00	0·00	32·10	14·32
1·66	2·93	8·35	No	Record			50·50	32·22 (Upto 27 July)
0·34	1·73	1·19	0·87	0·88	1·13	0·05	19·10	21·12
4·40	2·27	0·42	1·62	1·47	0·82	0·00	33·80	17·19
2·63	3·92	7·08	0·70	0·32	0·30	0·06	40·10	..

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for 19—31 August 1954

25	26	27	28	29	30	31	Total for August	Mean monthly rainfall
3·50	1·67	0·23	0·00	0·17	0·88	1·06	21·48	15·59
1·56	0·00	0·00	0·00	1·56	0·00	0·00	12·24	11·69
4·34	2·08	0·51	0·00	0·00	0·08	0·10	26·16	19·89
0·00	0·00	0·00	0·15	0·91	1·11	2·92	41·35	36·65
1·73	0·28	0·49	0·00	0·00	0·00	0·25	13·87	12·89
2·03	0·10	0·31	0·26	0·06	1·18	0·56	28·02	20·25
1·50	0·48	0·00	0·00	0·00	0·16	0·63	15·76	22·50
1·51	0·62	0·66	0·00	0·08	1·63	0·60	22·16	30·38
2·50	0·00	0·00	0·00	0·00	0·10	0·00	7·52	29·69
0·21	0·00	0·00	0·00	0·00	0·00	0·07	3·92	15·96
0·00	0·13	0·00	0·00	0·22	0·00	0·00	9·98	13·51
0·00	0·00	0·00	0·00	0·00	0·64	0·22	13·71	13·15
0·00	0·00	0·00	0·00	0·00	0·17	0·00	13·34	12·97
1·20	0·00	0·00	0·00	3·03	0·00	0·00	22·44	17·76
0·00	0·19	0·00	0·00	0·00	0·19	0·00	5·74	13·29
..	0·00	2·09	0·00	0·51	1·46	0·09	25·40	..

the four days—23rd to 26th—which is, indeed, a very heavy spell for that station. Daily rainfall at a number of stations in Nepal, north Bihar and Assam for the period 19 to 31 August are given in Table 2. Spells of heavy rain are given in bold types.

After the 25th, the axis of the monsoon trough shifted rapidly southwards, bringing to an end the ' break ' conditions. The rainfall over the hills also decreased considerably thereafter.

The chief features of August 1954, as far as the rains in the hills were concerned were similar to the condition in July of the year that were responsible for the July floods. But, the absence of the easterly wave and hence the feed of fresh monsoon air from the Bay of Bengal to the Eastern Himalayas, lessened the amount and intensity of rain considerably during August when compared to July. But, because of the favourable pre-existing conditions namely soaked ground and full rivers, the floods in August were of the same magnitude as those of July, though the rainfall was less in August.

To sum up, the heavy floods of July and August 1954 were the result of concentrated heavy rain over short periods in the Himalayas, caused by a combination of meteorological factors, *viz.*, persistence of ' break ' conditions with the axis of the monsoon trough shifted to the foot of the Himalayas, the passage of a number of active low pressure waves eastwards across these regions and the continued strength of the monsoon.

I am happy to acknowledge my thanks to Shri P. R. Krishna Rao, Deputy Director General of Observatories, who suggested to me the writing of this note and also kindly went through the manuscript. My thanks are also due to Dr. Pisharoty who supplied some data and also gave valuable suggestions after perusing the manuscript.

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