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FLASH FLOODS AND THEIR FORECASTING—A FEW CASE STUDIES

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SYNOPSIS

Flash floods occur from heavy rainfall and sudden overflowing of rivulets and streams into the low lying areas. They occur (i) from the movement of depressions/cyclonic storms (ii) the shift of the axis of the monsoon trough close to the foot hills during monsoon (iii) the incursion of southerly current from the Arabian Sea and the Bay of Bengal into the mountaineous regions of the Himalayas (iv) the development of off-shore vortices along the west coast during monsoon under the active equatorial trough.

On satellite imageries, the areas of intense convection coincide with the equatorial trough and the embedded cyclonic circulations at 500 hPa during the monsoon season and the cyclonic circulations at 700 hPa during the post monsoon season. During the pre-monsoon and sometimes during the post-monsoon seasons these coincide with the cyclonic circulations close to the ground (0.9 Km asl). Sometimes, there are no circulations associated with the intense convection but the ascent is provided to the southerly moist current by the mountaneous.

1. INTRODUCTION

Flash floods occur from heavy rainfall and sudden overflowing of rivulets and streams into the low lying areas. They also occur due to dam burst or inadequate drainage. In India flash floods are common during the rainy season from May to October. The meteorological factors responsible for the occurrence of flash floods or causing floods in the rivers have been linked with the systems which cause heavy rainfall (1,6). They are as given below (i) severe thunderstorms known as the cloud

bursts. These cause localised flash floods particularly in the hill areas e.g. the Himalayas, along the Western Ghats and the eastern slopes of Nilgiris. (ii) Depressions and cyclonic storms. In May and June depressions from the north Bay of Bengal moving northeastward cause severe floods over Assam. These depressions move west or northwestward during July and August giving heavy rainfall and causing floods along their track. Their recurving north or northeastward causes severe floods in the upper Ganga basin rivers. When such a depression or a well marked low pressure area tracks northwestward over Rajasthan and incursion of deep southerlies occur in the state of Jammu and Kashmir from the Arabian Sea we can forecast flash floods for Kashmir valley and Jammu from heavy rainfall along the mountain slopes and the flooding of the Sindh and Upper Ganga basin rivers (2,4,10). Tropical cyclones cause flooding of the Peninsular rivers as well coastal inundation. (iii) The shift of the axis of the monsoon trough close to the foot hills of Himalayas during monsoon season. In this situation heavy rainfall occurs in the upper Ganga Basin and Brahmaputra valley. The favourable meteorological situation is the formation of cyclonic circulations in the east-west mid-tropospheric trough along the foot hills and their interaction with the mid-tropospheric middle latitude westerly troughs.

In the present paper the authors have re-examined the possibility of forecasting the heavy rainfall areas with the help of synoptic charts and satellite imageries available at the forecasting offices in the light of recent developments. This has been done through a few selected case studies between 1979 and 1987. The cases are typical and have been selected off hand to make the view point clear. Some new findings are made about the distribution of heavy rainfall in association with the meteorological systems.

2. FLOODS IN ASSOCIATION WITH DEPRESSIONS.

Case - 1. Catastrophic flash flood near Morvi in Saurashtra in August 1979.

This case was very tragic one as it was associated with the bursting of a dam across the Machhu river in Saurashtra in the afternoon of 11 August between 1430 and 1500 IST. The worst affected area was Morvi town and the neighbouring villages about 6 Km downstream of the dam where a flood wave of 8-10 metres in height rolled down from the damaged Macchu Dam, Submerging everything in its path (6).

Fig.1 shows the streamline analysis of 700 hPa and 500 hPa levels at 00 UTC of 11 August. The 24 hours rainfall figures ending at 03 UTC of the day are plotted at 500 hPa. The centre of a depression on the mean sea level has been shown by the encircled dot at 700 hPa. It was 650 Km away to the northeast of Morvi, Rajkot the nearest Raingauge station reported 35.4 cm of rainfall at 03 UTC on 11 August. The very heavy

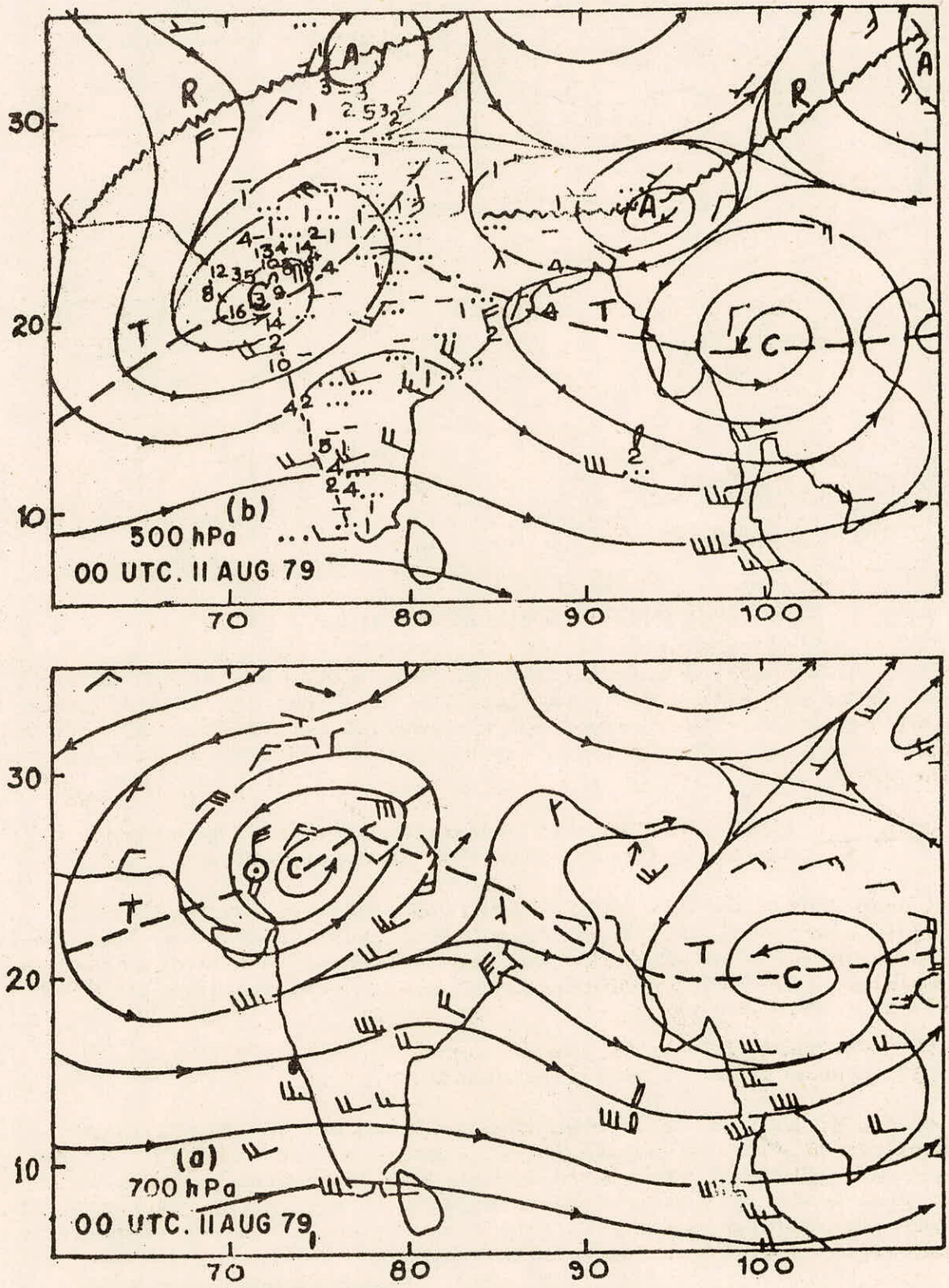

FIG. 1. STREAMLINES AND RAINFALL.

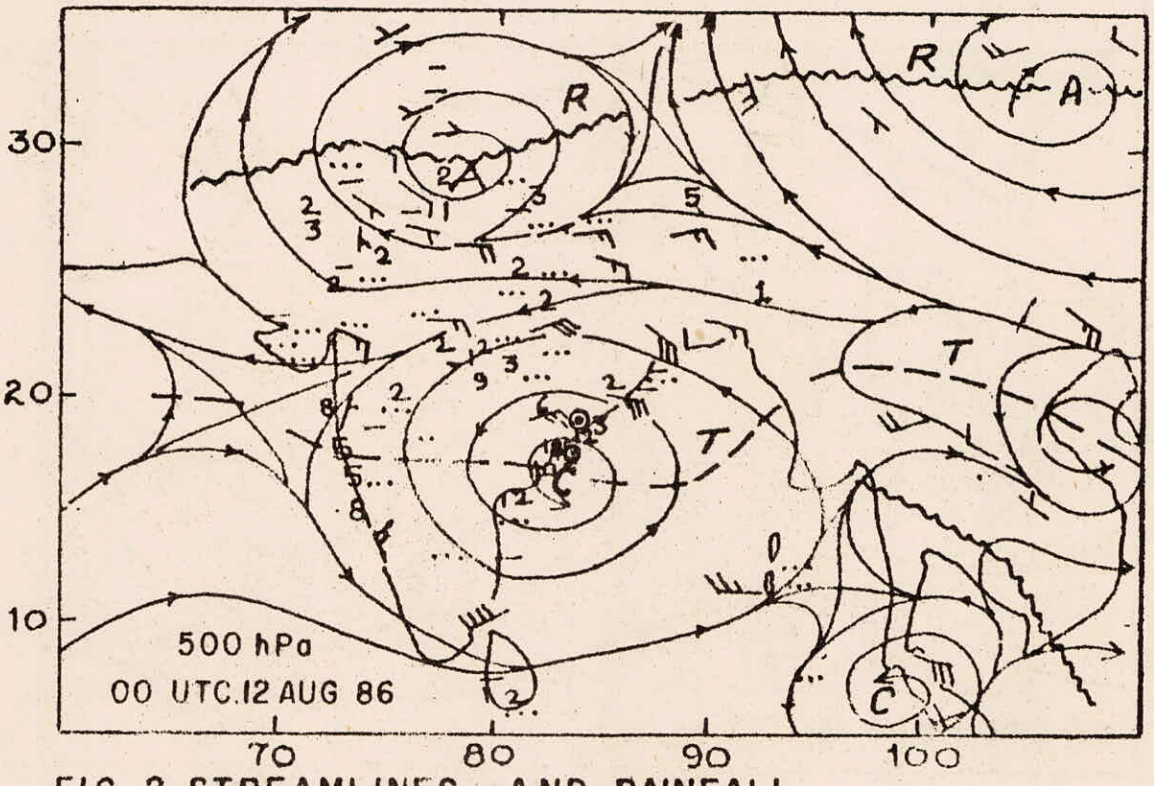

FIG. 2 STREAMLINES AND RAINFALL.

rainfall which occurred over the area must have been one of the major causes of the disaster. It is pertinent to note that the area of heavy rainfall coincided with the cyclonic circulation embedded in an east-west trough at 500 hPa. The cyclonic circulation at 700 hPa was located much to the north.

Case - 2. Flash flood in east Godavari, Guntur and Kurnool districts (Andhra Pradesh), 12 August 1986.

A deep depression over west central and adjoining northwest Bay, moving in a westerly direction crossed north Andhra coast near Kalingapatnam on the night of 12 August and lay centred at 03 UTC on 13th close to Jagdalpur. The significant rainfall amounts (cm) recorded at 03 UTC of 12 and 13 August were

12 : - Vishakhapatnam 18, Chandrapur 9
13 : - Chandrapur 24, Machilipatnam 11

In Fig.2, is shown the stream-line analysis of 500 hPa at 00 UTC of 12 August 1986. The 24 hours rainfall figures ending at 03 UTC of the day are also plotted. The centre of the deep depression on mean sea level lies to the northeast of maximum rainfall area along the coast. It is again interesting to note that the circulation at 500 hPa embedded in an east-west trough coincides with this area.

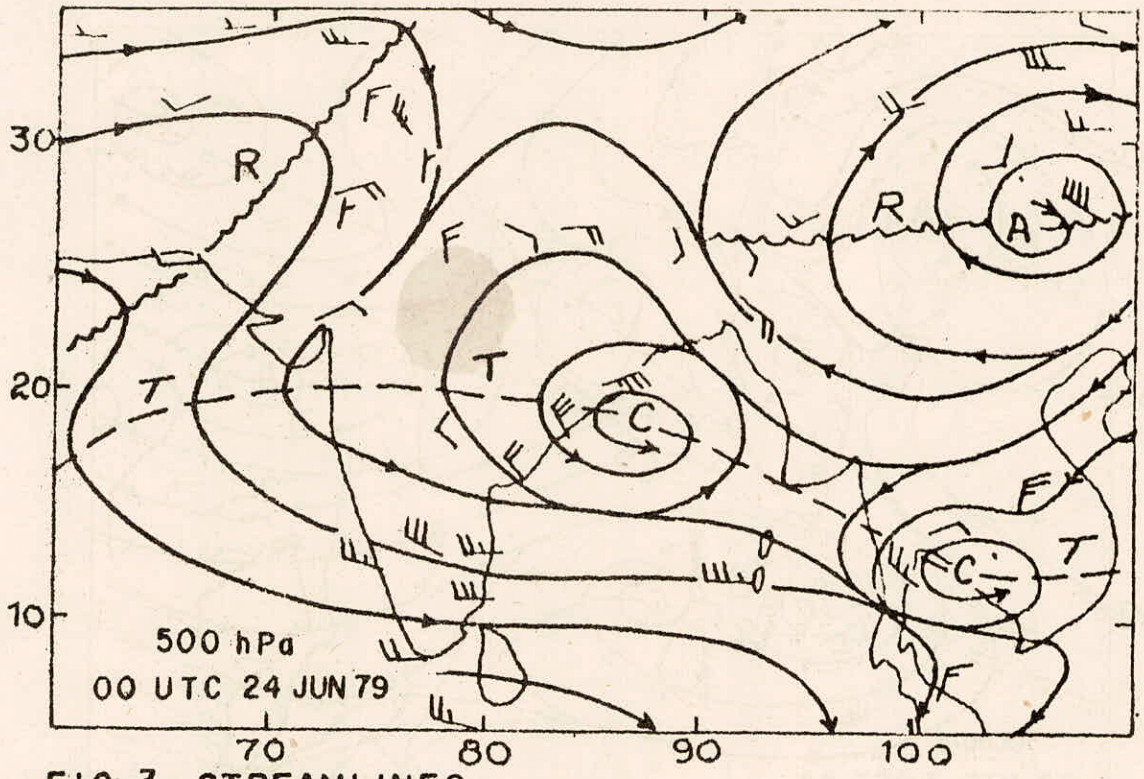

FIG. 3. STREAMLINES.

It has been hypothesised that during the westerly movement of depressions across India, heavy rainfall appears mostly confined to the southwest sector (3,5). The observation that the circulation at 500 hPa, in case of monsoon depressions, coincides with the heavy rainfall area appears more appropriate than the above said hypothesis.

3. FLASH FLOODS ASSOCIATED WITH THE EQUATORIAL TROUGH

Case - 3. Flash floods of Bombay 24 June 1979

Heavy rainfall occurred in Bombay on 24 June resulting in flash flood. This coincided with the following synoptic situation. A depression oformed in the west central Bay on the 23rd evening. This activated the east-west equatorial trough over Arabian Sea in the latitude of Bombay (Fig.3). As a result an off shore vortex with steep south-north pressure gradient (southerly owind over Bombay and easterly over Dahanu), formed at 00 and 03 UTC of 24 June. As a result heavy downpour occurred over Bombay which reported 15 cm of rainfall at Colaba observatory and 14 cm at Santa Cruz Observatory on 03 UTC of 24 June and 10 cm rainfall at Santacruz Observatory and 9 cm at Colaba Observatory on 03 UTC of 25 June leading flash flood.

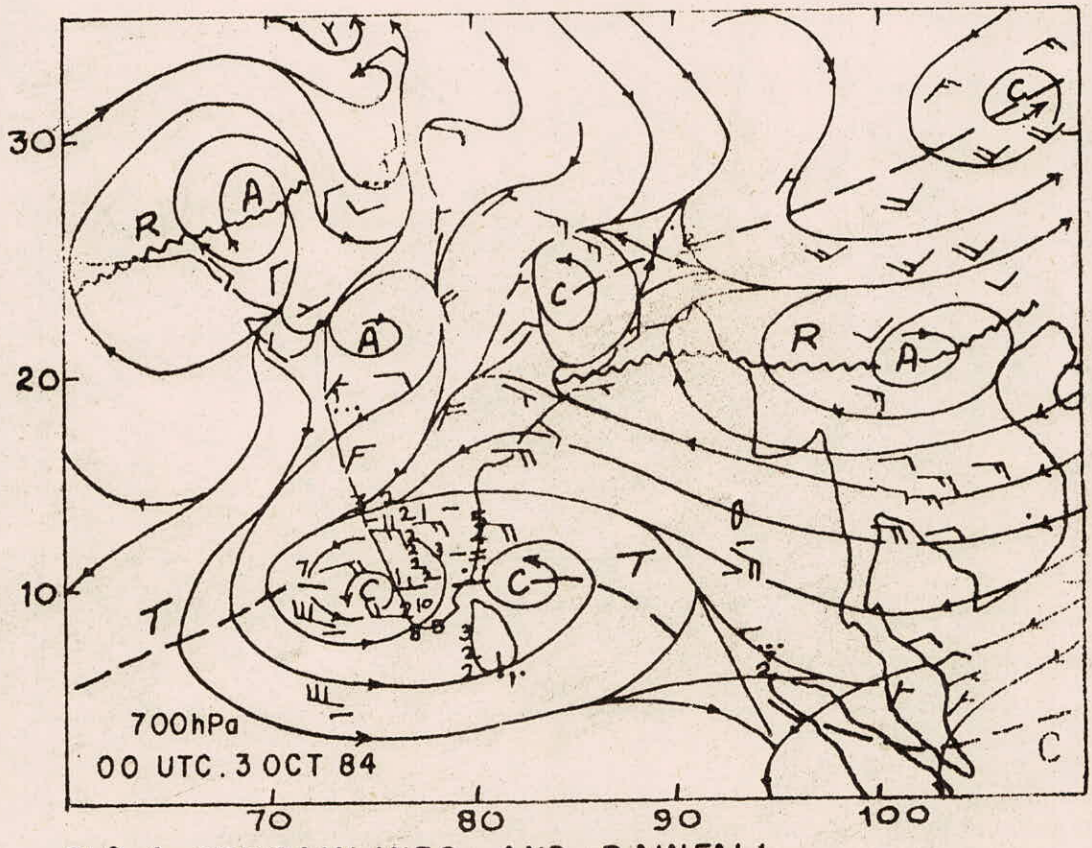

FIG. 4. STREAMLINES AND RAINFALL.

Case - 4. Severe flash flood in Sanganur Pallan Coimbatore District, 3 and 4 October 1984.

7 persons died in this flash flood. 2 persons died in wall collapse in Coimbatore city. 4000 people were rendered homeless. About 1000 huts located in low lying areas and on the banks of a river were washed away. Many building collapsed Flood water entered huts and houses in Sanganur, Rathnapuri, Sivananda Colony and Podanur. Fig.4 presents the stream line analysis of 700 hPa at 00 UTC of 03 October 1984 along with the daily rainfall figures for 24-hours ending at 03 UTC of the day. The distribution of heavy rainfall has coincided with the east-west equatorial trough with embedded cyclonic circulation formed off Kerala and off Tamil Nadu coast.

The equatorial trough forms over India from the northward movement of the equatorial zone of maximum cloudiness and appear at 500/700 hPa during monsoon/post-monsoon seasons. The convective activity is most pronounced in these when they arrive along 19-23°N/10-14°N in these seasons (9). At this time mid-tropospheric cyclones (MTS) form in them and concentrate into low pressure areas/depressions and cyclonic storms. Even otherwise, the MTCs give copious rainfall. During monsoon when such an ET at 500

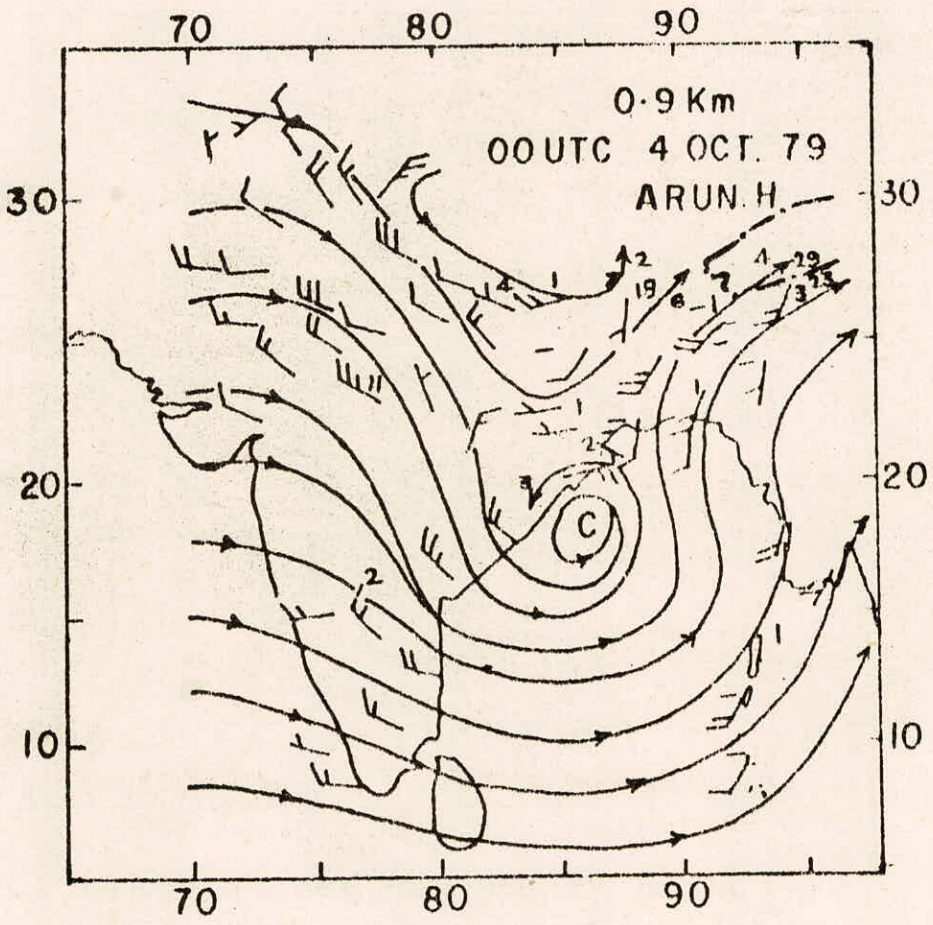

FIG. 5 STREAMLINES & RAINFALL

moves near the foot hills of Himalayas and interacts with the middle latitude westerly trough, heavy rainfall occurs and floods/flash floods, are reported in the Assam, West Bengal and Bihar rivers/down the slope plain areas.

4. THE BOUNDARY LAYER MOISTURE ADVECTION.

Case - 5. Flash flood of Lohit river of 4 October 1979.

Under the influence of the cyclonic circulation over the Bay of Bengal off Andhra coast, moisture incursion took place in the lower troposphere over NE India. The strong southerly flow was found over region east of 85°E. These winds on reaching the mountaneous ranges in the area shed their moisture leading to heavy precipitation causing flash floods in Lohit river on 4 October 1979 (Fig.5). The southerly flow became westerly at 1.5 and 2.1 Km, which suggest that the converging southerly flow was

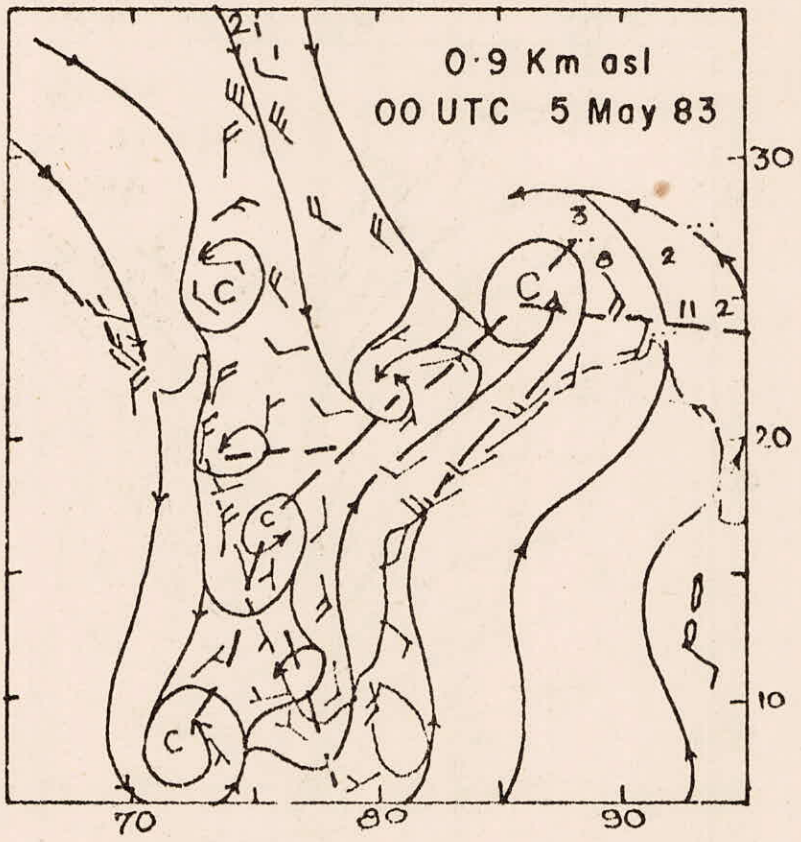

FIG.6 STREAMLINES AND RAINFALL

confined to the boundary layer. Maximum cloudiness zone aligned south-north was noticed over India south of the mountains in Arunachal Pradesh in the IR satellite imagery of 4 October. This suggests that the alignment of the cloudiness is representative of the moisture advection along the southerly current in the boundary layer.

Case - 6. Severe flash floods in North Tripura, 5 May 1983.

12 persons died in these flash floods, HQ town Kailashar was ucut off from rest of the state for 5 days.

A cyclonic circulation lay over Bihar Plateau and adjoining Gangetic West Bengal between 4-6 May. A trough at 0.9 Km asl extended from this system to south Maharashtra and than to south Peninsula on 5 May. Another east-west trough at 0,9 Km asl extended from West Uttar Pradesh to Nagaland, Manipur, Mizoram and Tripura across Bihar (Fig.6). The southerlies from the Bay therefore, took a cyclonic turning to form meso-scale cyclonic circulation at 0.6 Km asl over Tripura and adjoining Bangladesh. Silchar reported 11 cm of rain, Imphal 2 cm, Cooch Bihar 8 cm at 03 UTC of 5 May 1983.

Similar boundary layer phenomena causing heavy rainfall and as a result flash floods in NE India are observed during pre-monsoon and post-monsoon seasons. These circulation features are normally not observed above 1.5 Km asl. The formation and movement of mesoscale cyclonic circulations along these east-west and north-south trough lines can give severe weather like hail-storms and tornadoes (7,8).

5. DISTRIBUTION OF FLOODS AND FLASH FLOODS.

Frequencies of floods and flash floods were plotted sub-division wise for the period 1979-87. It was seen that the areas of high frequency of floods were not necessarily the areas of flash floods. The areas of upper Ganga and Brahamputra river basins spread over east Uttar Pradesh, Bihar Plains, West Bengal, Assam and Meghalaya form the maximum flood prone belt of north and northeast India. The second most affected area by the floods comprises of Narmada and Godawari basins, Madhya Maharashtra, Gujarat and Saurashtra. They also occur in the river basins of Punjab, Himachal Pradesh and Jammu Kand Kashmir State. Floods occur in Orissa, Andhra Pradesh when cyclonic storms strike the coast. The incidence of severe floods in Peninsular India is minimal.

On the contrary, the entire belt of foot hills of the Himalayas, the western belt along the Western Ghats, the eastern slopes of the Nilgiris, get the maximum number of flash floods. Low lying areas in Gujarat, Rajasthan, Orissa, Tamil Nadu and Andhra Pradesh are also prone to flash floods under high intensity rainfall.

6. DISCUSSION AND CONCLUSION.

The seasonal and spatial distribution of floods and flash floods can be linked with the northward propagation of the equatorial trough to its active phase (9). During monsoon season, when the equatorial trough at 500 hPa lies between 19°N and the foot hills of Himalayas, floods and flash floods occur in Northern India in association with the formation of low pressure areas and depressions. During the post monsoon season when the ET is active along 10-12°N, flash floods occur in the southern India.

It is also seen that the areas of heavy rainfall associated with the monsoon depressions coincide with their cyclonic circulations at 500 hPa. On the satellite cloud imageries, the cloudiness associated with the depressions coincides with the circulations at 500 hPa. We can therefore, conclude that the circulation at 500 hPa, lies over the main convective area of a depression during monsoon. This circulation slopes north or northeast ward as it descends to the mean sea level. This is in keeping with the temperature distribution. Hence, the depressions are found to slope north to south or southwestward with height (11) and heavy rainfall

appears to be concentrated in their southwest sectors (3,5). During post monsoon the areas of heavy rainfall coincide with the circulations 700 hPa/850 hPa.

During premonsoon and sometime in post monsoon season heavy rainfall and flash floods occur when the southerly moist current sheds its moisture on reaching the mountaneous slopes or when it feeds cyclonic circulation embedded in an east-west trough in the boundary layer. The satellite imageries can be of great help in identifying such areas.

REFERENCES

1. Abbi S.D.S., 1981, Flash flood and their forecasting, Meteorological Monograph Hydrology No.17/1981, I.Met.Dep., New Delhi-110 003.
2. Anantha Krishnan, R. and K.L. Bhatia, 1960, Monsoon of the World, India Met.Dep., pp 157-172.
3. Bedekar, V.S. and A.K. Banerjee, 1969, A study of Climatological and other Rainfall patterns over Central India, Indian J. Met. Geophys., 20, pp 23-30.
4. Ghosh S.K. and K. Veeraraghavan, 1975, Severe floods in Jammu and Kashmir in August 1973, Indian J. Met. Hydrol. Geophys., 26, 2, pp 203-207.
5. Pisharoty P.R. and G.V. Asnani, 1957, Rainfall around monsoon depression over India, Indian J. Met.Geophys., 8, pp 15-20.
6. Ramaswamy C., 1987, Meteorological aspects of severe floods in India, 1923-1979, Meteorological Monograph Hydrology, No.10/1987, I. Met. Dept., New Delhi-110 003.
7. Ranjit Singh, 1981, Mausam, On the occurrence of tornadoes and their distribution in India, 32, 3, 307-314.
8. Ranjit Singh, 1985, A synoptic and sub-synoptic scale study of tornado that occurred in Orissa in 1981, Vayu Mandal, 15, 3&4, 02-96.
9. Ranjit Singh, 1987, General circulation and the south-north oscillation over Indian region during MONEX 1979, Vayu Mandal, 17, 1&2, 32-37.
10. Ranjit Singh, 1987, Mausam, Meteorological study of severe floods in Jammu and Kashmir, 38, 3, 319-324.
11. Sarker, R.P. and A. Chowdhury, 1988, Diagnostic structure of monsoon depressions, Mausam, 39, 1, 9-18.