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A meteorological study of severe floods of August 1976 in Jammu & Kashmir

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सार — इस शोधपत्र में जम्मू एवं कश्मीर के उन भीषण बाढ़ों का मौसम विज्ञान सम्बन्धी अध्ययन किया गया है जो अगस्त 1976 के प्रथम दो सप्ताहों के दौरान एक के तुरंत बाद दूसरा आये थे। एक अवदाब के उत्तरपश्चिम दिशा में बढ़ने और उसके तुरंत बाद राजस्थान के ऊपर से दूसरे सुस्पष्ट निम्नदाब के कारण बंगाल की खाड़ी और अरब सागर से जब आर्द्र दक्षिणी पवनों का अन्तर्वहन हुआ तो राज्य के ऊपर स्वतन्त्र रूप से उष्ण कटिबंधीय लक्षणों वाले वातावर्त बने। इन वातावर्तों के कारण भारी वर्षण हुआ जिसके फलस्वरूप राज्य में भारी बाढ़ें आईं।

ABSTRACT. In this paper a meteorological study has been made of the severe floods that occurred in two quick successions in Jammu & Kashmir State in the first two weeks of August 1976. Vortices, with tropical characteristics, formed independently over the State when deep incursion of moist southerlies took place from the Bay and the Arabian Sea due to northwestward movement of a depression followed by another well marked low over Rajasthan. These vortices gave heavy precipitation which resulted in severe floods in the State.

1. Introduction

Though the instances of floods in Jammu & Kashmir State are not many, they have been very devastating particularly in Kashmir valley. These have occurred due to the depression recurving over Rajasthan in a northerly or northeasterly track towards the State (Ananthakrishnan and Bhatia 1960), which results in heavy falls, while it has also been suggested that the deep penetration of moisture over this area occurs even in the the presence of low in the lower tropospheric levels associated with the trough in upper air westerlies with an embedded jet stream (Ghosh & Veeraraghavan 1975).

Jammu & Kashmir State experienced heavy rains in August 1976, causing much devastating floods. The Kashmir valley lies below the level of river *Jhelum* and it is protected from the flood by the earthen embankments. The river was in spate for nine days with torrential rains in the valley. The flood situation in such cases is further aggravated by the melting of deposited snow and ice at higher levels by falling rains. The heavy flow of water downstream caused breaches in the embankments worsening the situation to a stage when the partial evacuation of Srinagar and other valley cities became necessary. These floods took a toll of about 68 human lives and damage to property and crop ran into many crores. Besides thousand of pilgrims of Amarnath shrine cave were stranded.

The deluge which persisted for nine days occurred due to two systems a depression followed by another well marked low which moved northwestward over Rajasthan. The study has been made using the NOAA satellite imagery available for the period.

2. Synoptic evaluation

A depression formed over West Bengal on the morning of 28 July and moved in the westnorthwesterly direction. It was centred near Jaipur on 31 July while another low pressure area was activated in the Bay on the same day (Fig. 1).

The flow patterns at 12 GMT of 31 July at 850 and 500 hPa levels are presented in Figs. 2 (a & b). The moisture is being advected into the cyclonic system both from the Arabian Sea and Bay of Bengal extending upto 500 hPa. The deep incursion of moisture taking place into the Kashmir valley, is evident from comparing the 00 GMT and 12 GMT sounding of Srinagar on 31 July and 1 August (Fig. 3). A trough in the upper air westerlies at 300 hPa which was located west of 75°E provided the upper air divergence. The conditions were, thus, ripe for the heavy rainfall over the State. Sensing this, the Meteorological Centre, Srinagar issued necessary warnings to the population over the public telecommunication system, apart from acquainting the administrative machinery of the possible consequences. Unprecedented floods followed on 1 August due to heavy precipitation aggravated further by topography of the area as well as possible melting of snow at higher reaches of the mountains.

Upto 2 August, the system gave heavy falls in valley. It weakened with moist flow being cut-off from the sources and moved further northwest to Pakistan on 3 August. A temporary relief was, thus, accorded to the State and there was recession in the floods. The formation and growth of the weather system under the influence of moisture incursion from the Arabian Sea

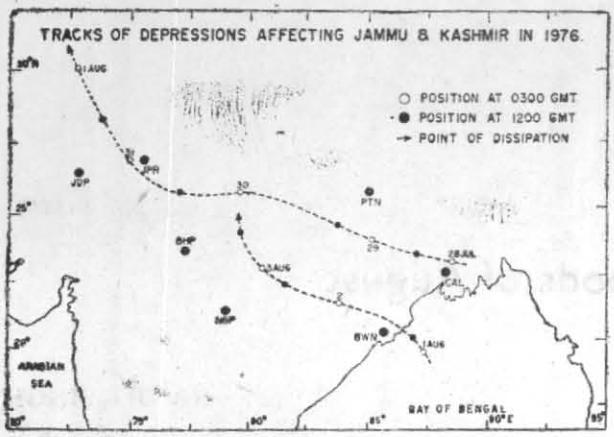
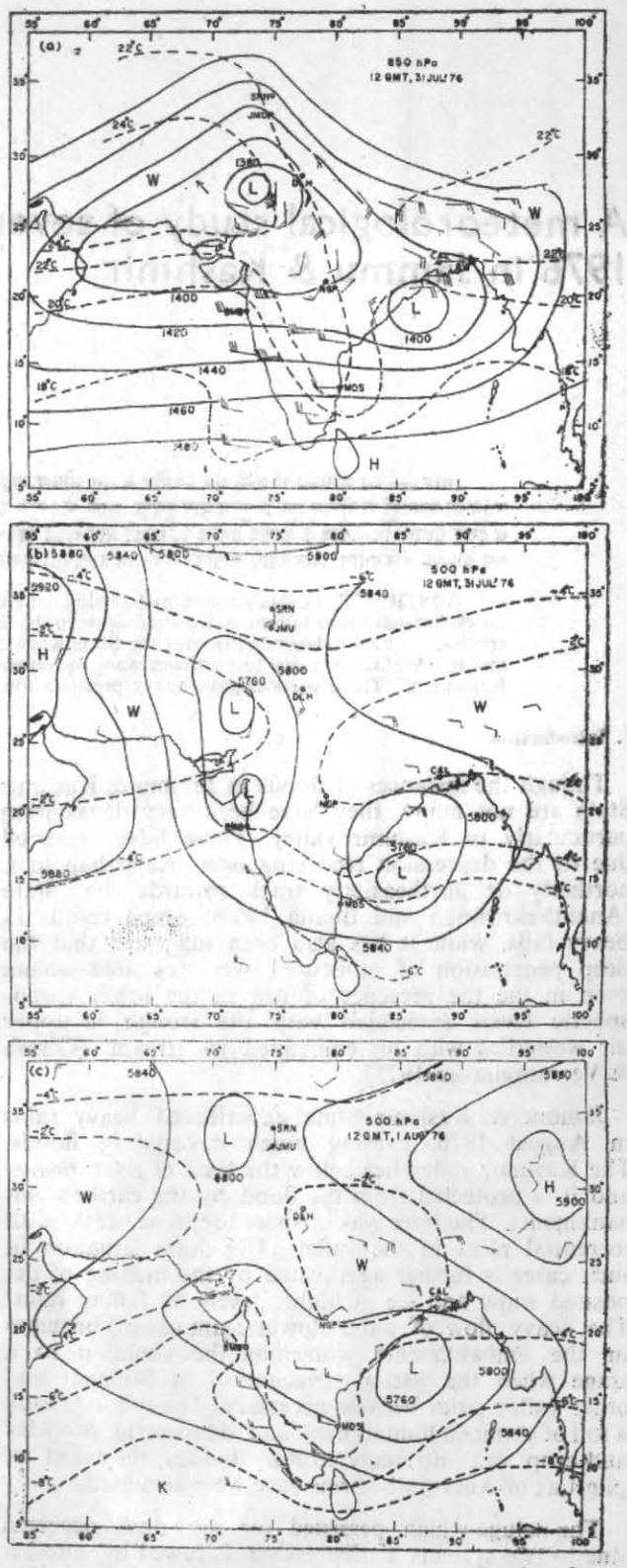


Fig. 1. Tracks of depressions affecting Jammu & Kashmir in 1976

and and Bay of Bengal and its dissipation when this moisture supply is cut-off have been distinctly depicted by the morning visible NOAA-4 satellite imageries of 31 July, 1 and 2 August 1976 [Figs. 5(a-c)].

The other low pressure area over the Bay intensified into a deep depression, moved in the northwesterly direction and lay over east M.P. on 3 August. On 4 August, however, it weakened and was situated as a well marked low over the central M.P. The flow pattern at 12 GMT on 4 August at 850 hPa level depicts that the moisture incursion has taken place into Jammu region (Fig. 4a), the penetration of moist current extending upto 500 hPa. A north-south trough in the westerlies at 300 hPa interacted with the system and thus, on 5 August, heavy falls were reported in the Jammu region to the extent that at Reasi, a rainfall of about 20 cm was recorded in a day.

On 00 GMT of 5 August the system moved northward and the wind over Srinagar came into its circulation. On 6th morning, however, the system bifurcated into two lows at 700 and 500 hPa levels, the northerly one of which could be located over Jammu & Kashmir [Fig. 4(b & c)]. A fresh upper air westerly trough moved over the region. This resulted in the renewal of precipitation which again brought floods into the State. The second onslaught of floods made matters precarious for the valley where the earthen embankments on the river *Jhelum* had breaches at many places along its course and threatened Srinagar city. From 7 August onward, though conditions improved in Kashmir valley, Jammu region continued to reel under floods till 10 August. Reasi again recorded a rainfall of 15 cm on 7 August. The evening IR satellite imagery of 4 August, morning visible imagery of 6 August [Figs. 6(a & b)] depict the formation and movement of weather system over Jammu & Kashmir State on these days under the influence of moisture incursion from south, whereas morning IR satellite imagery of 7 August (Fig. 6c) depicts the cloud vortex over Punjab and adjoining hills of west Uttar Pradesh (U.P.) and Himachal Pradesh (H.P.). Rainfall (in mm) recorded by India Met. Dep. observatories and some State raingauges of Kashmir division between 1 & 10 August 1976 is shown in Table 1.



Figs. 2(a-c). Contour and isotherm patterns showing low pressure areas at 12 GMT on 31 July at 850, 500 and on 1 August 1976 at 500 hPa

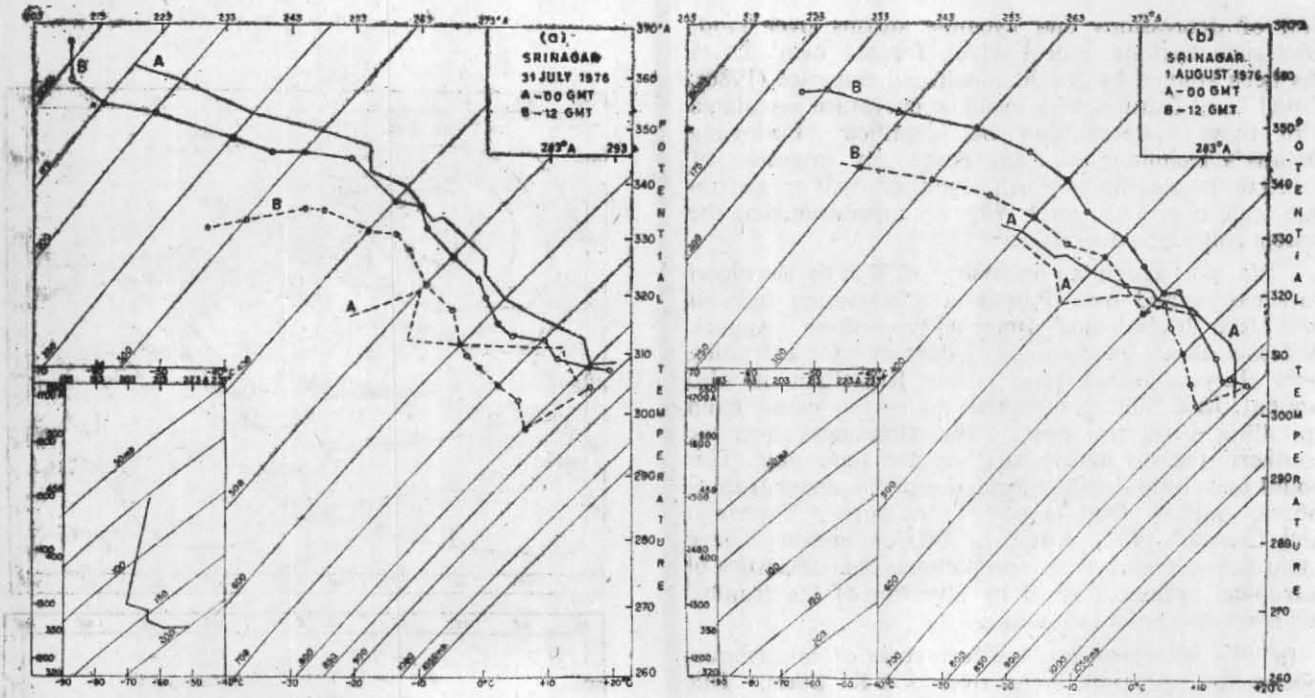


Fig. 3. Tephigram curves of 00 and 12 GMT on 31 July and 1 August 1976

TABLE 1

Rainfall in mm for the month of August 1976

Station	Dates (August 1976)									
	1	2	3	4	5	6	7	8	9	10
Srinagar	30.2	44.7	2.6	0.0	6.6	2.0	3.2	11.1	6.5	0.0
Banihal	96.3	77.4	0.0	0.0	28.8	46.8	49.4	17.0	4.0	0.0
Varinagh	231.2	86.2	3.4	1.0	31.8	66.0	57.2	29.0	7.9	—
Qazigund	152.0	126.0	0.0	0.0	22.0	46.0	31.4	24.2	3.6	0.0
Shopian	131.0	34.2	—	—	27.0	16.5	38.0	—	33.2	—
Gulmarg	35.5	54.4	7.5	—	—	0.0	22.5	—	—	—
Jammu	5.8	55.3	0.0	0.0	3.0	—	28.0	15.0	45.6	—

3. Discussion

Thus, we find that guide lines given by Ananthakrishnan & Bhatia (1960) and Ghosh & Veeraraghavan (1975) are very effective for the forecasting of floods in J&K State. However, in the present case some important observations of further interest were made which could be possible only recently with the help of available NOAA imageries. We shall discuss the same in paras to follow.

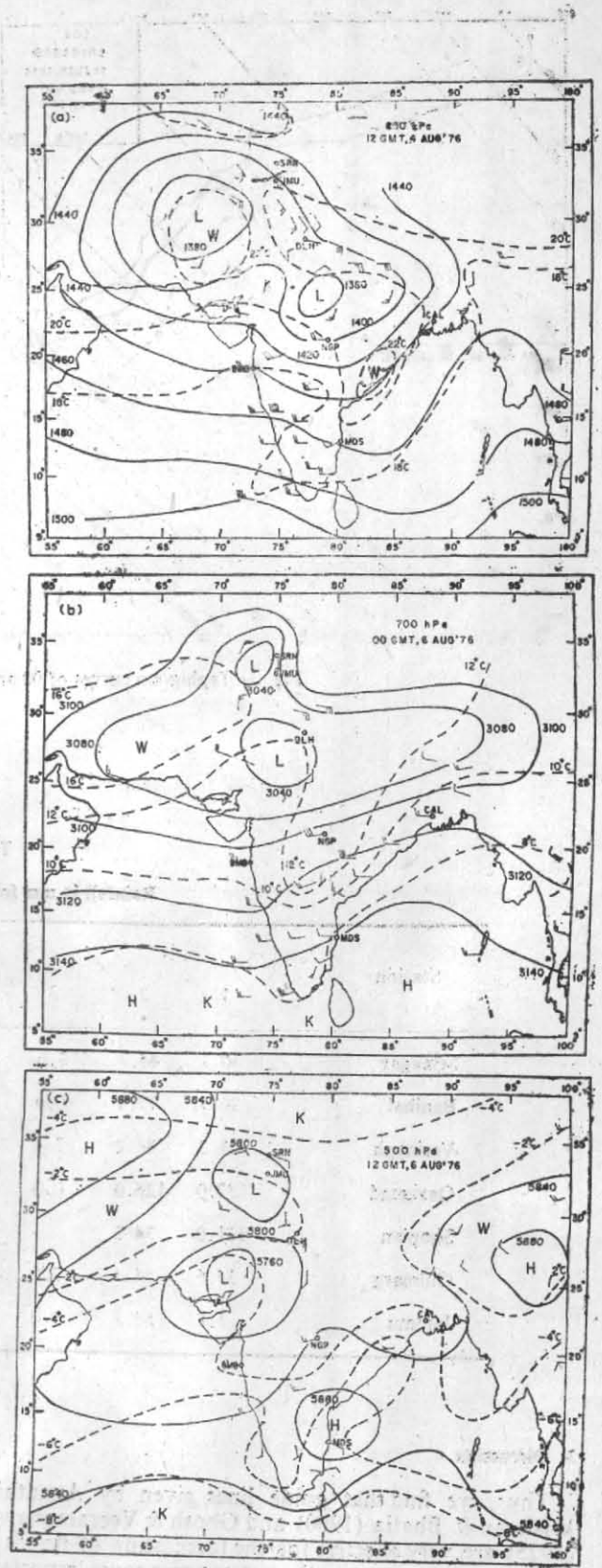
(*i*) Satellite imageries have been helpful in identifying the vortex cum spiral features of the cloudiness in the above two cases. Dvorak (1982) has developed techniques for intensity analysis and forecasting of cyclonic vortices using satellite pictures for systems forming over the sea. However, during monsoon season, there is ample supply of moisture over north India from the Arabian Sea as well as the Bay of Bengal and the lower and middle tropospheric layers become as moist as over the sea, facilitating the forma-

tion of depressions and cyclonic storms over land. One such cyclonic storm which formed near Delhi has been studied by Ranjit Singh and Banerjee (1980). Cloud band features with cyclonic curvature associated with these systems can be identified. Following Dvorak's technique we can assign an intensity of T 1.5 to the cloudiness which organised itself on a synoptic scale over J&K on 1 August, suggesting that the system could be a depression.

We can assign an intensity of T 2 to the cloud vortex organised over Punjab and adjoining hills of west Uttar Pradesh and Himachal Pradesh on 7 August. A feeder cloud band around 2 degrees wide extending over Haryana and adjoining west Rajasthan is also present. J&K State got rainfall under the cloud band spiralling from the north. The cloudiness over the southern regions disappeared on the same day. This could have been due to subsidence of the upper tropospheric outflow from the cyclonic storm. Thepenier and Cruette (1981), using the NOAA imagery, have identified a system with spiral cloud characteristics of a tropical cyclone, formed by advection of the tropical air mass into polar latitudes.

(*ii*) We witnessed here the formation of mid-tropospheric low pressure areas over J & K State. This can be explained on the following lines. The southerly flow associated with the northwesterly moving cyclonic disturbance has brought moisture over the State. Over Srinagar, this flow is observed to be pronounced extending upto 500 hPa on 31 July and 1 August. Encountering the upper air westerly trough, these winds veer with height. This feature in the proximity of Himalayan ranges generates large scale orographic convergence and vertical motion resulting in well organised convection which is followed by the formation of independent mid-tropospheric circulation over the region; as according to Ooyama (1982), cyclogenesis develops in an area of organised convective activity. In the cases studied formation of the new vortices have nothing to do with the original systems.

(*iii*) Fig. 7 presents a vertical time section of height and temperature anomalies over Srinagar from 00 GMT of 30 July to 12 GMT of 7 August 1976 obtained by subtracting the normal values of standard pressure levels for the month of August (based on data 1951-1970). Relative humidity (RH) was also computed and plotted at different levels with 100 hPa spacing. 03 GMT and 12 GMT surface observations are plotted at the base. The four westerly troughs that have moved across J & K are shown as T_1, T_2, T_3 and T_4. Of these T_2 did not give any significant weather due to want of a moisture source. The part of figure between 30 July & 2 August is similar to the Fig. 6 of Ranjit Singh and Banerjee (1980). Height anomalies are, in general, negative and decrease uniformaly with height. They are minimum at 100 hPa at 12 GMT of 31 July and lay superposed over minimum in temperature anomalies at 200 and 150 hPa. This was in response to the passage of an upper air westerly trough T_1 over the station. Development of this feature over Srinagar, in the presence of continuous moisture supply from the Arabian Sea, was followed by an intensification and reorganisation of convection. A rise in temperature by 2°-4°C was observed in the lower tropospheric levels at 00 GMT on 1 August and Srinagar winds strengthened to southerly 52 k at 500 hPa. These were due to the release of latent hea



Figs. 4(a-c). Contours, isotherms and winds at 12 GMT on 4 August at 850 hPa and 00 & 12 GMT on 6 August 1976 at 700 and 500 hPa levels

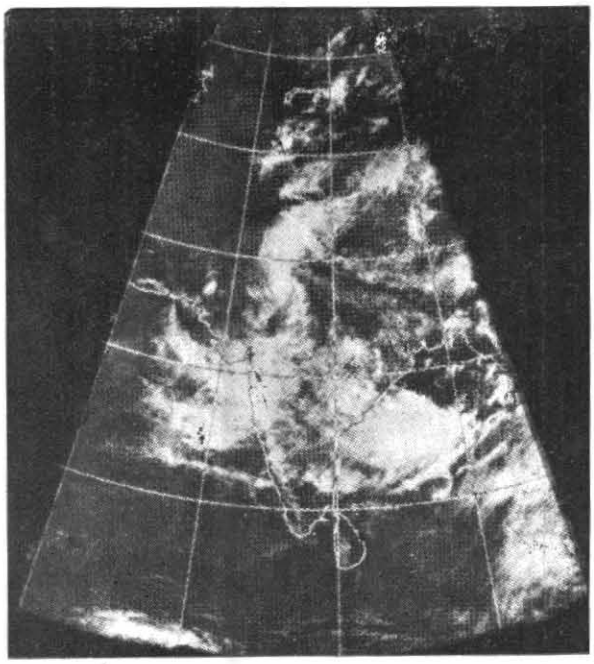


Fig. 5 (a)

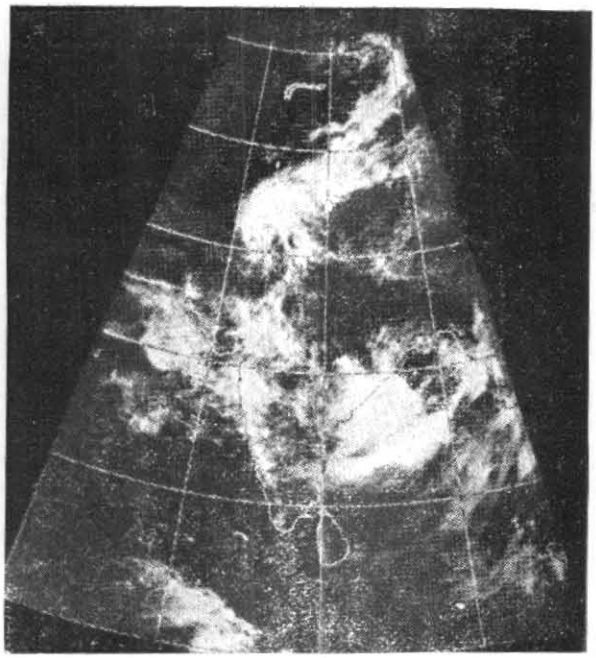


Fig. 5 (b)

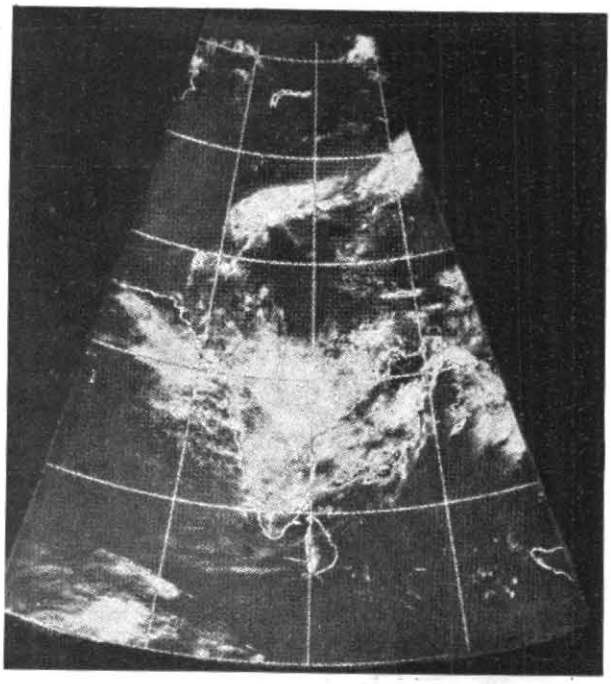


Fig. 5 (c)

Figs. 5(a-c). Satellite imageries (VIS) from 30 July to 2 August 1976

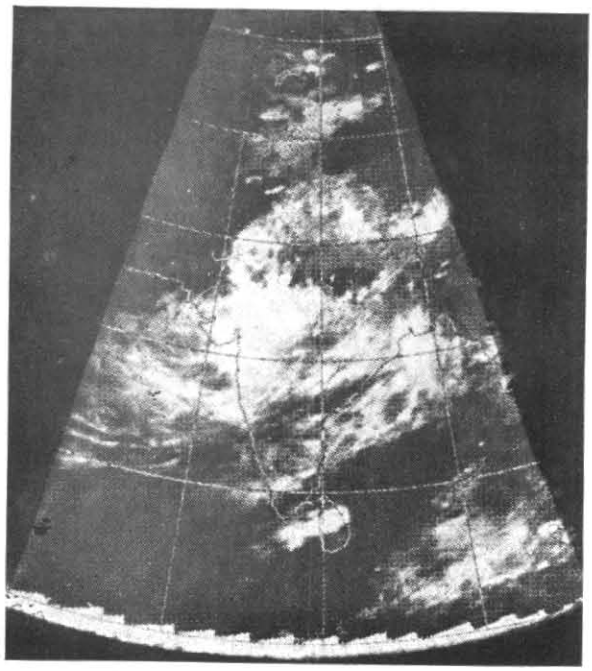


Fig. 6 (a)

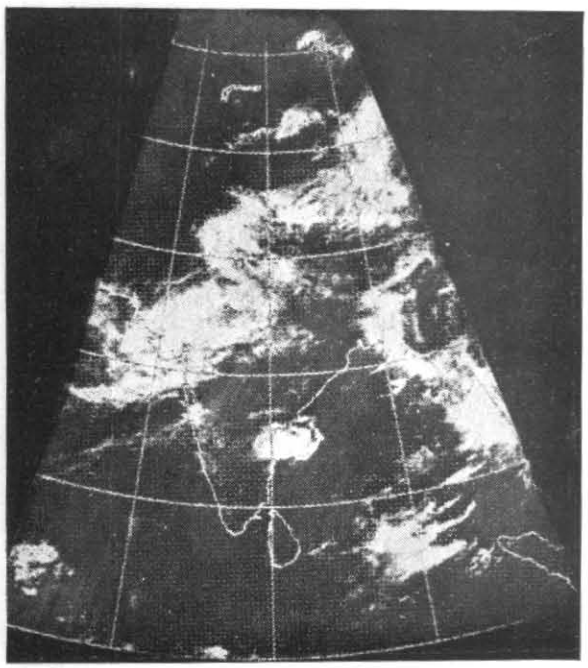


Fig. 6 (b)

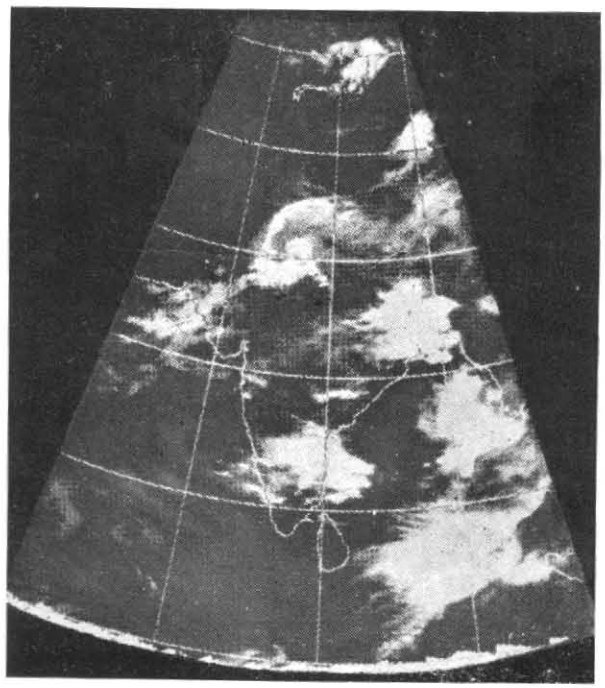


Fig. 6 (c)

Figs. 6 (a-c). Satellite imageries (VIS & IR) of 4 to 7 August 1976

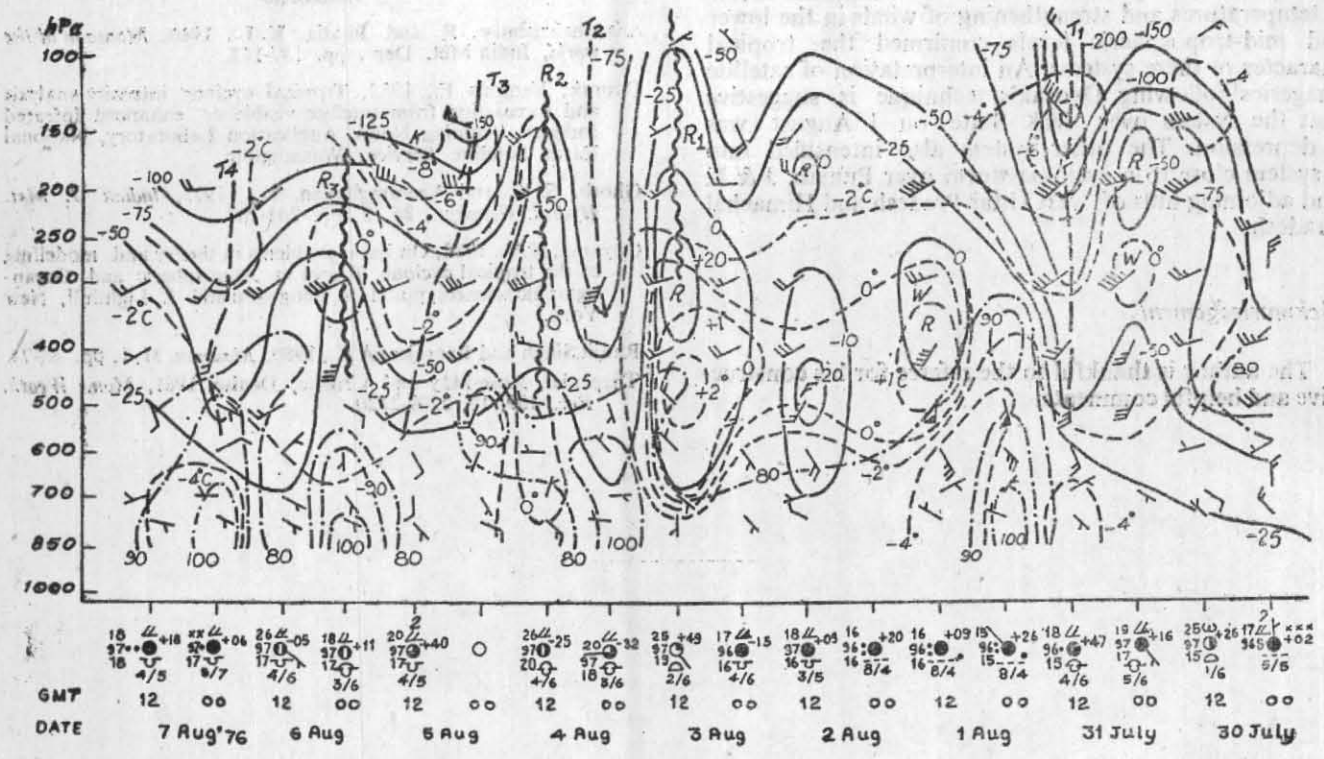


Fig. 7. Vertical time section of winds, gpm height, temperature anomalies and relative humidity over Srinagar for the period 30 July to 7 August 1976
——— gpm height; — — — — temperature anomalies; — — .——.——. relative humidity

during heavy rainfall. This heat was also responsible for the positive trend in height anomalies above 500 hPa from 00 GMT of 1 August. The RH value increased with time and was maximum at this hour when the isopleth of 80% RH extended well above 400 hPa. In the second spell of rainfall between 4 and 7 August, Peshawar wind strengthened to NNE/50 kt at 700 hPa at 00 GMT of 6 August when a mid-tropospheric circulation formed in response to the cloud organisation over Punjab, J&K and adjoining Pakistan. Patiala and Shimla reported SE'ly winds of 30 and 40 knots respectively at 0.9 km asl at this hour. This strengthening of lower and mid-tropospheric winds is typical of tropical storms at the time of their intensification.

(*iv*) Referring to the soundings on 31 July (Fig. 3) 2-4°C fall of temperature is noticed at different levels between 00 GMT and 12 GMT. It is accompanied by a rise of dew point temperatures above 600 hPa while below this level their fall is significant. This renders the 12 GMT soundings conditionally less unstable compared to 00 GMT. These observations have the following explanation. When the moist southerly current first arrives over the State, the airmass is raised under the combined effects of orographic convergence and upper air divergence. This will result in a general adiabatic cooling. Because of the vertical motions, condensation will occur in the moist airmass. At Srinagar this airmass will undergo subsidence because of descent into the valley. The condensed water droplets, therefore, may re-evaporate extracting heat from the atmosphere and generating cooling. The increase in moisture above 600 hPa and it's depletion below this level may occur from the vertical transport of this re-evaporated moisture by the afternoon convection. Similar phenomena was noticed at 12 GMT of 1 August. This kind of relative dryness in the lower layers of tropical cyclones as a result of greater convective activity over continental locations has also been discussed by Keenan and Templeton (1983).

(*v*) The average height of the freezing level over Srinagar is 5 km during this season. Heavy downpours occurring from such systems of tropical origin as the ones described above will dislodge and melt the snow and ice deposited at higher reaches of the mountains which further aggravates the flood situation particularly in the Kashmir valley.

4. Conclusion

Whenever some monsoon depression or a well marked low pressure area tracks northwestward over Rajasthan and incursion of deep southerlies occurs in Jammu & Kashmir State, from Bay and Arabian Sea we can forecast flood in the region. Srinagar soundings and satellite imageries can be utilized for this purpose.

The floods of August 1976 which came in two quick successions resulted from the formation of independent circulations over the J&K State on the two occasions.

Widespread heavy rainfalls and the simultaneous rise in temperatures and strengthening of winds in the lower and mid-tropospheric levels confirmed the tropical character of these systems. An interpretation of satellite imageries following Dvorak's technique is suggestive that the system over J&K State on 1 August was a depression. The other system also intensified into a system close to a cyclonic storm over Punjab, J & K and adjoining hills of west Uttar Pradesh and Himachal Pradesh.

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