PATTERN OF PRECIPITATION UNDER THE TROPICAL DEPRESSION – SEASONAL LOW INTERACTION

Abdul Majid*, Muhammad Riaz*, Muhammad Javaid Iqbal*

Abstract:

Merger of the tropical depression with the seasonal low results in the accentuation of the seasonal low causing the generation of the strong Southwest flow within the lower troposphere along the South eastern Sind and adjoining Punjab. However prior to its merger into the seasonal low the tropical low pressure system (LPS) causes wide spread precipitation over Sind and adjoining Punjab as it moves West/Northwest wards across Sind. Thus the first rainfall spell is generally followed by the dry period of 01 – 02 days, when the LPS having shed the moisture becomes relatively insignificant to the extent that it becomes almost untraceable on the surface map. However in case a strong westerly wave is moving across the Northern latitudes, then under its influence LPS moves Northwest wards to merge into the seasonal low. The second rain spell is then caused by the accentuation of seasonal low. This meteorological situation constitutes an important meteorological phenomena resulting in two rain spells widely separated in time and space. The weather and flood forecaster often fails then succeeds in forecasting the second rain spell. The paper brings out the details of the LPS – westerly wave interaction culminating in the merger of the LPS into the seasonal low and resulting pattern of precipitation with special reference to the case study of flood of July 1989.

Introduction:

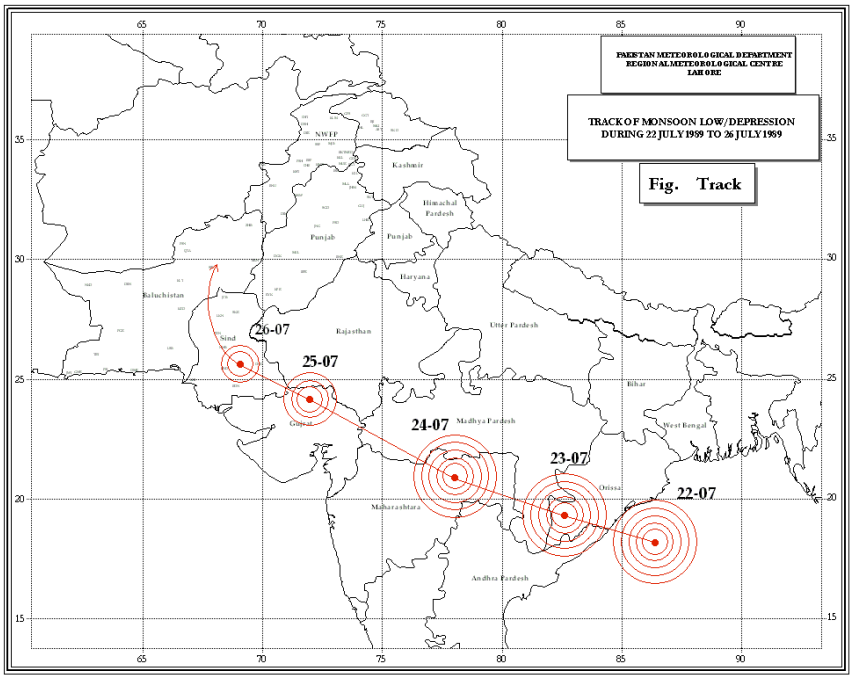
Tropical low pressure systems constitute the most significant rain producing weather systems in the Indo Pak sub continent. Occurrence of the weather and rain along the track of the approaching LPS is a usual phenomenon. The amount of rain and the extent of the precipitation region in this situation is related to the intensity and coverage of the LPS, which can be judged by its vertical extent and its areal spread. Extrapolating the future movement of the LPS then becomes the major concern of the weather and/or flood forecaster. However under special situation the LPS continues to move Westward (upon reaching Rajasthan) to reach lower Sind causing the heavy rain under its direct effect. At this point the LPS may fall under the grip of a westerly wave moving along the Northern latitudes and recurve towards North to merge into the seasonal low. The low may then cause strong Southwest currents from the Arabian sea extending up to 700 mb or more. The moisture laden maritime flow from the Arabian sea causes the heavy monsoon rains, which may cause floods under the intensified seasonal low condition. A forecaster tends to be deceived by the loss of identity of the LPS on the surface map and thus may forecast dry weather for the subsequent few days, whereas the LPS may still

* Pakistan Meteorological Department.

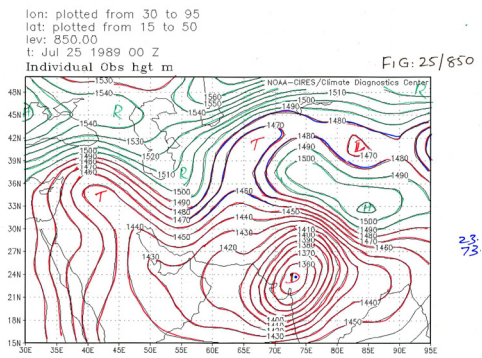
be significant in the lower troposphere. The situation causes two rainfall spells widely separated in time & space and thus constitutes an important meteorological situation of the summer monsoon season. The July 1989 presents the typical such situation as discussed in the paper with all the necessary surface and upper air meteorological maps. The upper air charts are the archived charts based upon the satellite data obtained from the international sources utilizing the internet facility.

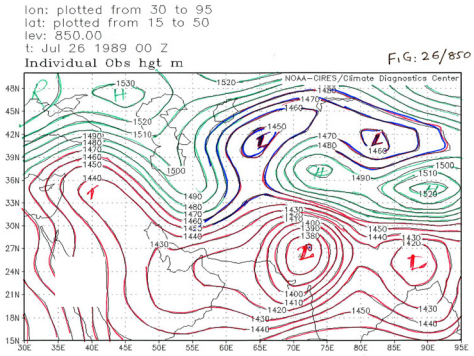
Meteorological Situation:

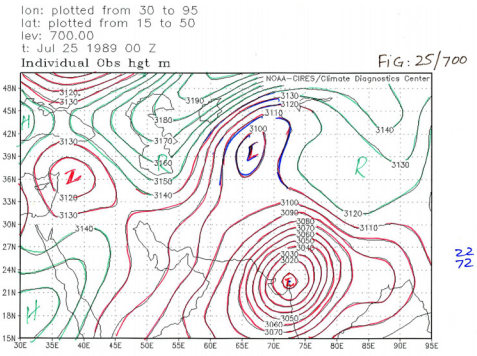
The LPS was first seen off the coast of Orissa (in the bay of Bengal) on 22nd July. On 23rd it arrived over South Western part of Orissa. At this stage the depression was very intense with five closed isobars (drawn at 02 mb interval). It continued to move along Northwest to arrive over Eastern part of Maharashtara on 24th with the intensity still intact. From this point onwards it moved rather fast and arrived at North Gujrat on 25th. The intensity was reduced to that of three closed isobars. Track of the LPS is indicated at the fig named "Track".

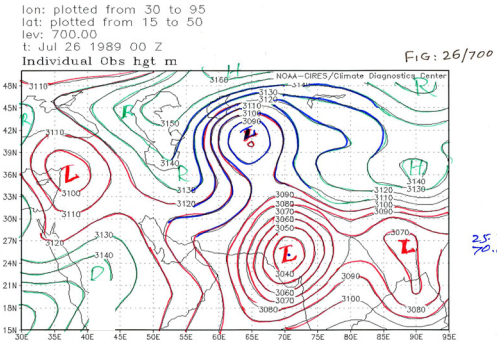


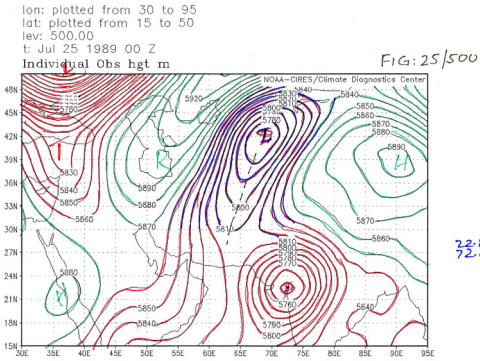
On 26th the LPS could be located over South Eastern Sind with its intensity reduced to two closed isobars. At this point the depression came under the grip of the westerly wave and under its influence started to recurve towards North. The intensity of the depression is indicated by its vertical extent up to 500 mb level with its axis tilted in the Southwesterly direction as indicated by the constant pressure (CP) charts of 850, 700 and 500 mb of 25th and 26th July 1989, shown at figures 25/850, 25/700, 25/500 and 26/850, 26/700 and 26/500 respectively.

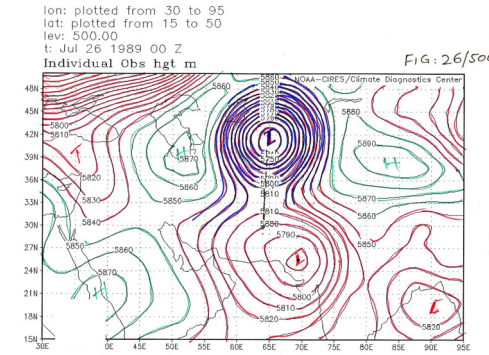




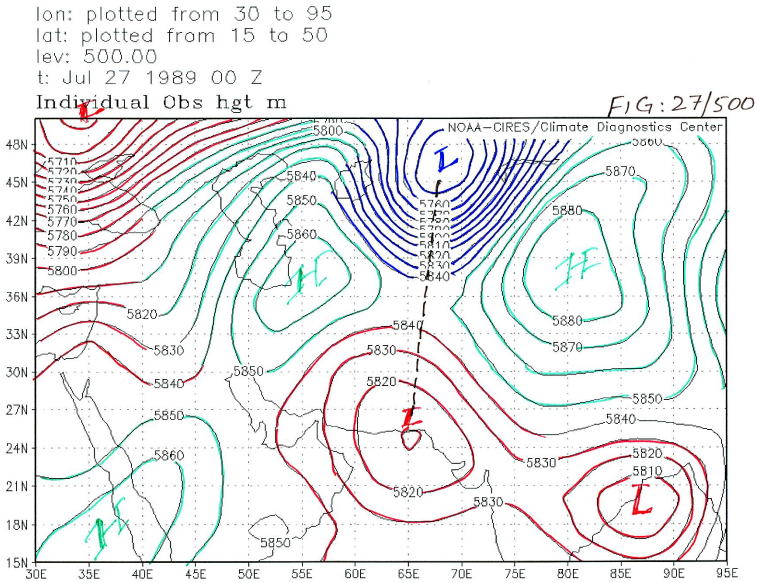




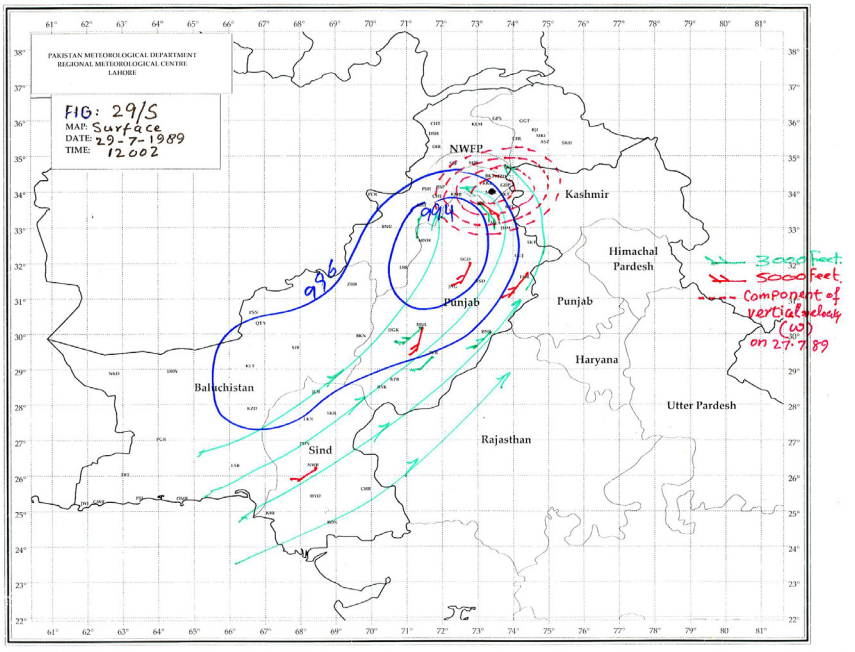




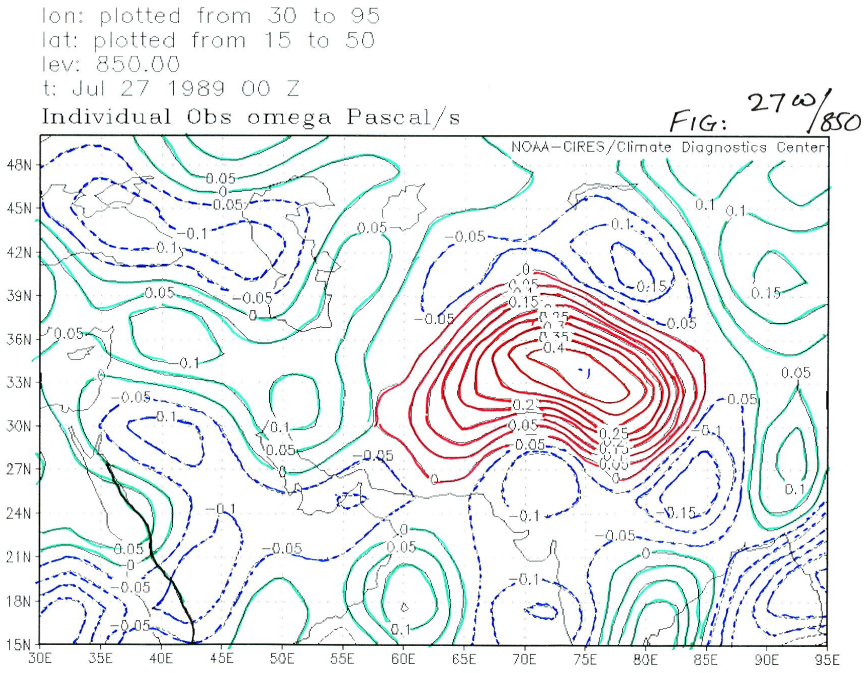
A westerly wave was clearly indicated on the 0000Z, 500mb chart of 25th July (fig. 25/500). The position of the wave was however still west of the position of the monsoon low. On 26th the westerly wave in the upper air became further intensified (fig. 26/500) while remaining at about the same location. A high to the east of the westerly wave restricted its Eastward movement. On the other hand the monsoon low continued to move West-Northwestwards and could be located over Southeast Sind on the surface map. The intensity of the low reduced to that of the two closed isobars. The monsoon low and the westerly wave got roughly oriented along the North-South axis as shown in the fig. 26/500. This disposition caused the monsoon low to curve further Northwards. By 27th the westerly wave and the monsoon low were mutually juxtaposed along the North-South axis as shown in the map given at fig 27/500.



Figures 25/500, 26/500 and 27/500 indicate the successive position of the LPS with respect to the westerly wave. From 27th onwards the seasonal low moved Northwards and later towards Northeast. The intensified seasonal low got extended along NE-SW direction with the centre of the low over North Punjab and adjoining NWFP as shown in the fig 29/S. The lower tropospheric wind flow is also indicated in the figures in green colour.



Another positive indicator of the formulation of the lower tropospheric cyclonic vortex over Northwest Pakistan (NWFP and adjoining Afghanistan) is the creation of the centre of vertical lifting of the air mass wherein the positive values of the vertical component of the wind field is shown centered over Northwest Punjab and adjoining NWFP, which approximately corresponds with the centre of the positive omega (vertical velocity) values at 850 mb level of 27th July 1989 as given in the fig. 27ω/850.



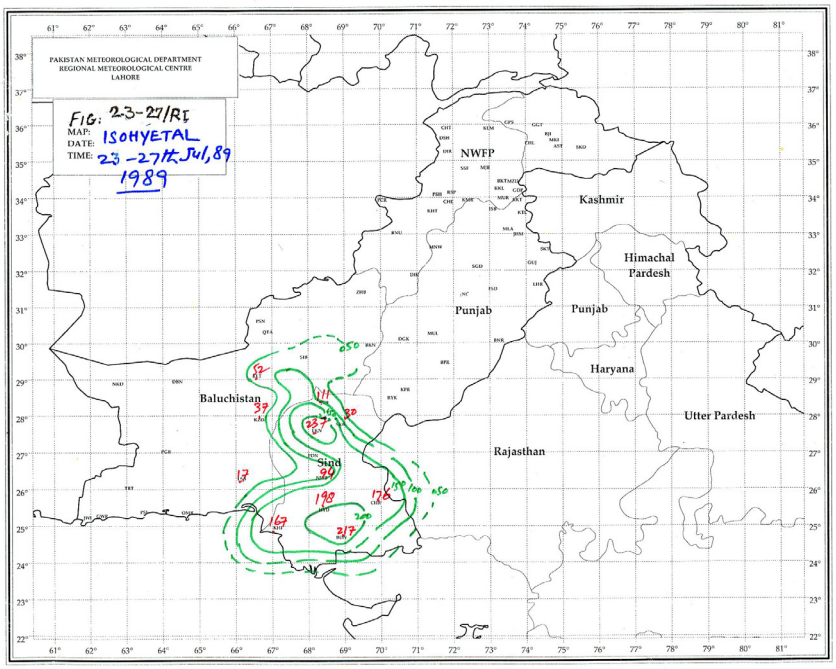
The vertical lifting of the air mass started a few days earlier to create a surface low and low tropospheric vortex resulting in the Northwards extension of the seasonal low. This situation caused the heavy rainfall over North Punjab, NWFP and Kashmir from 29th onwards as indicated in the isohyetal map shown at fig. 29-31/R2. The area of the maximum omega values is also superimposed upon the surface chart of 29th at fig. 29/S in red colour.

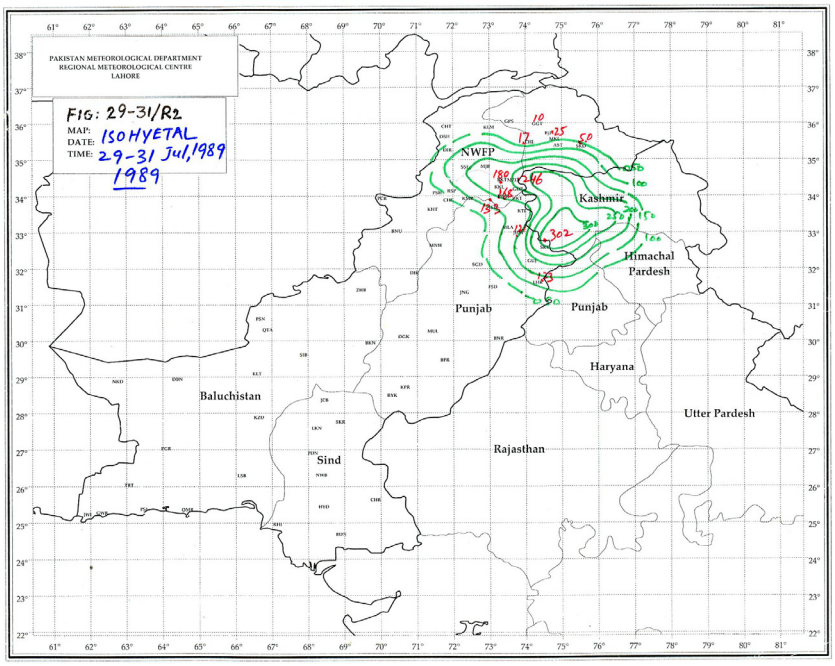
Rainfall Distribution:

Rainfall in Pakistan occurred in two distinct spells. First spell occurred on account of the direct effect of the monsoon low from 23 – 27th July over Sind and adjoining Baluchistan as shown in fig 23-27/R1. The second rainfall spell occurred due to the indirect effect of the monsoon LPS, by its merger into the seasonal low which resulted in the accentuation and its elongation in the N-S direction to form the low centre over North Punjab and adjoining NWFP, (fig 29/S). The isohyetal map of this rainfall spell for the period 29-31st July is given in the fig 29-31/R2.

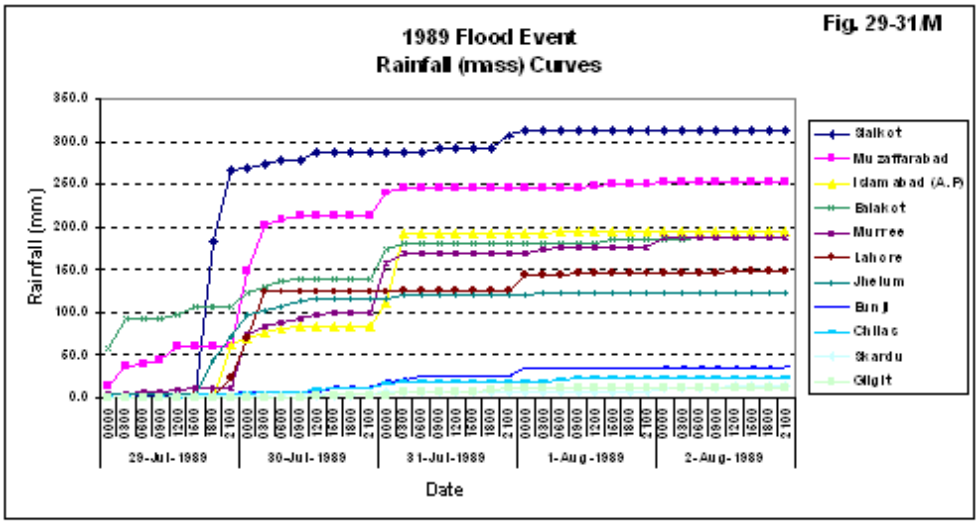
The rainfall was mainly confined to the area over Northeast Punjab and adjoining Kashmir. There were repeated rainfall spells over the three days from 29th to 31st July over the area. This pattern of rainfall is typical of accentuated seasonal low situation,

when the South westerly wind flow from the Arabian sea is drawn up to the Northeast Punjab, adjoining Kashmir and NWFP from surface up to about 10,000 ft.





The sequence of rainfall in case of second spell is as shown by the mass curves of the selected rainfall stations (fig 29-31/M).

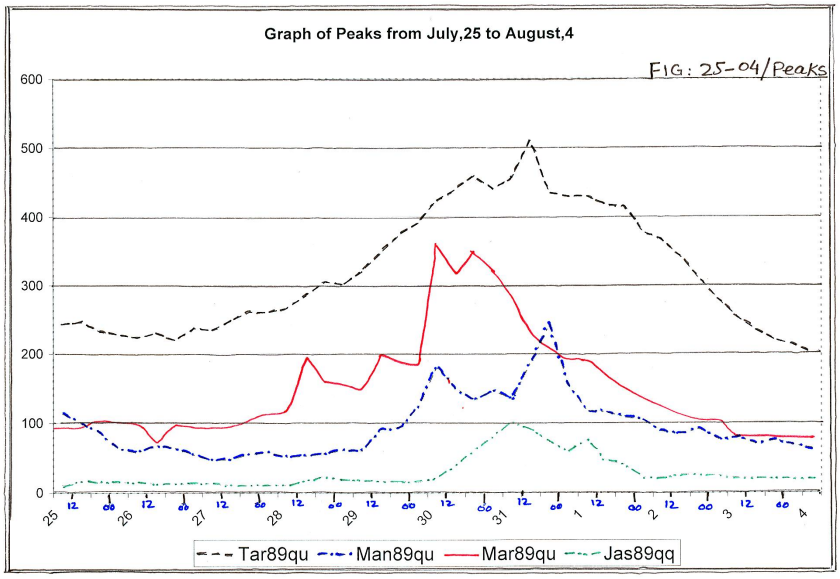


Rain first started at Balakot and Muzaffarabad region in the early morning on 29th, followed by that at Sialkot, Jhelum and Islamabad after about 20 hours. Lahore was the last to receive the rainfall which took place about 6 – 10 hour after its occurrence at Islamabad and Jhelum. This North-South movement of the rain front was caused by the stacking of the cold moist air mass along the mountain ranges to North. Beginning of the rain to the North was due to the orographic effect which gradually shifted Southwards on account of the stacking of the cold air which behaved similar to a mountain range in creating an artificial barrier to the Northwards moving moist air.

Flood Situation:

Floods mostly occurred due to the rainfall caused by the accentuation of the seasonal low after the merger of the monsoon LPS into it. Repeated Cat-I peaks occurred at Mangla and Marala during the period from 29th of July to 01st of August 1989. Marala received three repeated peaks starting from 28th to 30th July 1989. River was flowing at around one lac cusecs up to 28th when the rain started to cause the first peak of about two lac cusecs. The base flow did not fall below 1.5 lac, when the second peak arrived to raise the flow to 2 lac cusecs. The third major peak occurred towards the midday of 30th, which amounted to about 3.6 lac cusecs, and continued for about 15 – 20 hours. At Mangla two peaks of 1.8 lac and 2.4 lac cusecs occurred with a gap of 24 hours.

The most significant peak is the one received at Tarbela, in which case the river started to rise from 28th onwards. A peak of more than 5 lac cusecs occurred on 1200 hours of 31st July. The rise and the fall was gradual. Consequently the peak carried tremendous volume amounting to 6.5 maf. The set of peaks in the rivers Indus, Jhelum, Chenab and Ravi at their respective rim stations is given in fig “peaks”.



Inferences Drawn from the Study:

a) The LPS generally moves along the ITF and due to its overland movement results in the reduction in its intensity.

b) The track of the LPS is strongly influenced by the position of the Tibetan high at the middle & upper tropospheric level. Southwards shift of the Tibetan high shifts the ITF Southwards.

c) Heavy rainfall shall occur in the Southwest sector of the LPS.

d) The situation may cause extension of the seasonal low to North and Northeast. Indication to this effect shall come from the Omega (Vertical velocity) contour map, as the region of the high positive omega values shall be the region where the cyclonic vortex shall tend to form at the lower tropospheric levels causing the extension of the seasonal low to North/Northeast.

e) LPS upon reaching the position when the westerly wave to the North and the LPS to the South get mutually juxtaposed along the North-South axis, starts to accentuate and also to move Northwards to merge into the seasonal low, if the LPS has reached Southern Pakistan.

f) It shall normally take 1 – 2 days (after the merger of the LPS into the seasonal low) to generate the Southwesterly wind flow over Sind and adjoining Rajasthan to reach the mountainous regions of Punjab, NWFP and Kashmir. Consequently the rains may start 1 – 2 days after the merger of the LPS into the seasonal low.

g) The rains shall first start over Kashmir and adjoining NWFP and Punjab.

h) The rain front shall recede gradually Southwards to eventually cause the rainfall over Northern Punjab as well.

i) The rain shall follow the typical monsoon pattern, e.g., starting late night/early morning and clearing towards the midday. This pattern may be repeated over a number of days depending upon the intensification of the seasonal low.

j) The lesser the tilt of the vertical axis of the LPS, the stronger the system. Normally if the system maintains its vertical axis up to 600 hpa, it shall be a strong system causing strong Southwest moisture inflow from the Arabian sea resulting in the heavy rainfall in the Southwest sector of the LPS.

k) Significant flood peaks mostly limited to Cat-I shall be generated at the rim stations of the rivers Chenab, Jhelum and Ravi. Repeated peaks up to three or four may occur at the rim stations of the rivers Chenab and Jhelum.

l) Accentuation of the seasonal low due to the merger of the monsoon depression/low into it is the most important flood related meteorological situation for Tarbela. A prolonged significant peak corresponding to medium/high flood limit may occur. This shall carry tremendous volume due to gentle slope of the rising & falling limbs of its flood hydrograph.

References:

K. Shudiram Saha and Suranjana Saha (July 1993), "Variation and structure of a westward-propagating monsoon depression"., Mausam, Vol 44, No. 3

B. Shyamala, S. Sudevan, G.M. Shinde and M.D. Burte. (July 2001), "Behaviour of recurving cyclonic storms in Arabian sea, a response to atmospheric interaction"., Mausam, Vol. 52, No. 3

N.B. Thade, V.R. Mishra & D.S. Desai. (Oct 1992), "Unprecedented heavy rain in parts of Andhra and Maharashtra during 23 to 25 July, 1989 – Synoptic study"., Mausam Vol. 43. No. 4

Desai, D.S. 1987., "Field of vorticity, divergence and vertical velocity associated with break and strong monsoon 1987"., Mausam, Vol. 38, No. 4