UPPER TROPOSPHERIC WESTERLY TROUGH AS AN INSTRUMENT FOR THE DEVELOPMENT INTENSIFICATION AND NORTHWARD MOVEMENT OF THE TROPICAL LPS – WITH REFERENCE TO CASE STUDY OF SEPTEMBER 1988 FLOOD EVENT

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Abstract:

Influence of the westerly waves upon the tropical low pressure system is a fact known since many years now. However the paper brings out the impact of the upper tropospheric (500 mb) westerly trough on the low pressure as a means of development, intensification and northwards movement of the LPS. The study is based upon the case study of September 1988 flood event which is one of the major historic floods of Indo-Pak for the rivers Bias, Sutlej and Chenab.

Introduction:

Flood of September 1988 is one of the highest historic floods for the rivers Sutlej and Bias. The flood was caused by extremely heavy rains across the border in the upper catchments of the river Sutlej, Bias, Ravi and Chenab. Source of precipitation was the tropical low pressure system which could be located over Rajasthan on 23rd September. Low could not be traced back to the Bay of Bengal and thus was generated over the equatorial trough (ET) south of Gujrat state in the Arabian Sea at around 20° N. Development of the LPS, its intensification and its movement Northwards is clearly attributed to the approach of the upper air westerly trough associated with the westerly low pressure centered at 47° N as indicated in map at Fig. 24 C.

The most surprising element in this case was the fact that LPS on the surface did not move out of North Rajasthan, while the heaviest downpour occurred over Himachal Pardesh and Kashmir in India. This confused the Indian meteorologists also and resulted in some shortfall in the rain and flood forecast.

On the other hand luckily the PMD issued timely flood warning on 24th September. At the time when the rain was mainly confined to the areas across the border. This forecast was however not readily accepted by the Relief Commissioner, Punjab due to wrong advice of the Punjab Irrigation Department, which held the view that the flood across the border must be reported by the Indian Irrigation Department, through the Commission for Indus Waters as provided in the agreement between India and Pakistan.

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Later on, it came out that the flash flood in the rivers Chenab, Ravi, Bias and Sutlej in India was so sudden that the personnel posted at the discharge stations over these rivers had to run for their safety, while the entire communication system was destroyed in few minutes. Consequently no flood information arrived from India. On the other hand the flood warning of the PMD was not accepted until the floods actually hit at the rim stations of the rivers Chenab, Ravi and the irrigation personal in here too ran for their safety. At Jassar over Ravi for example last discharge value actually measured amounted to 120000 cusecs after which no discharge was actually computed, while this same value was repeated by the Irrigation Department for the subsequent 20 hrs until the error was pointed out by the PMD and from that time on "no data" was reported. Thus a timely warning issued by PMD was not acted upon and the nation had to pay heavily for the failure of the Relief Department Punjab.

Meteorological Situation:

The major features of the Meteorological situation are as under.

Formation of the tropical low pressure system (LPS) on the equatorial trough (ET) at around 20°N, south of the Gujrat state of India.

Approach of a westerly wave with associative upper air westerly trough west of 70°E.

Development of the LPS at ET is caused by the divergence aloft under the effect of upper air westerly trough resulting in the strong SW wind flow at 500 mb and above.

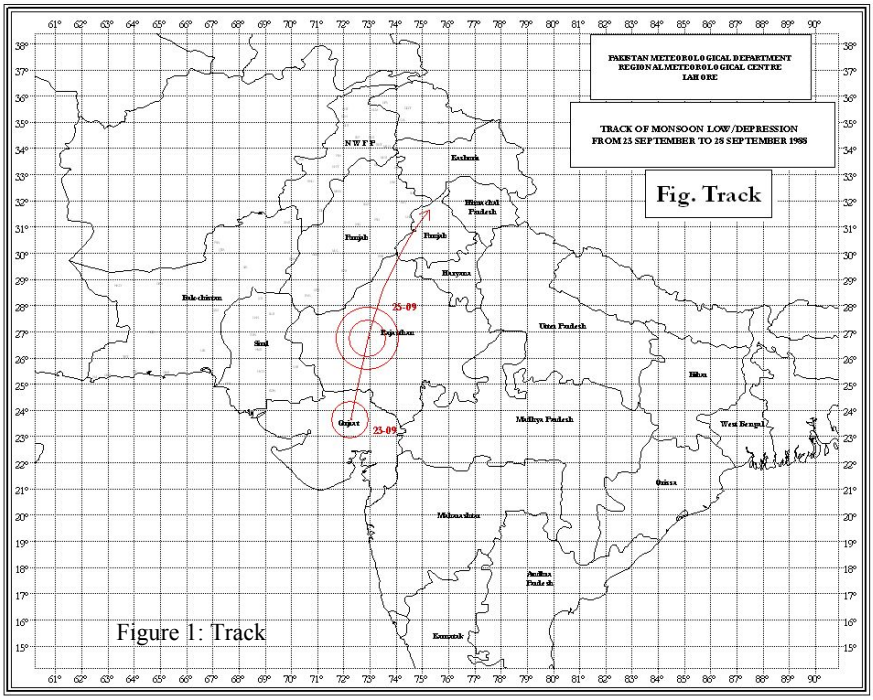
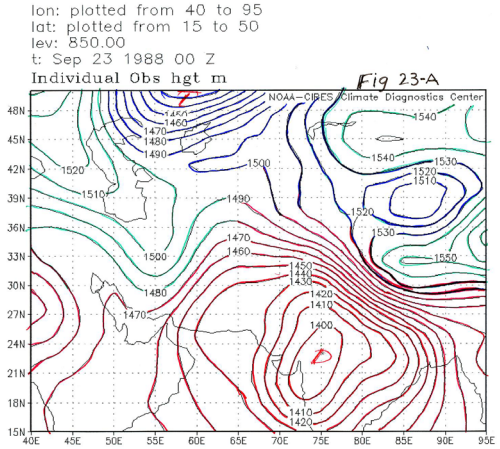
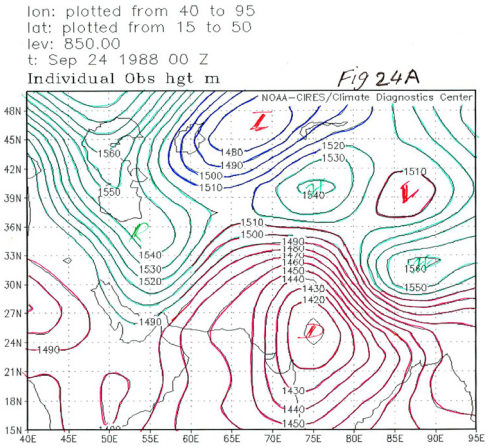


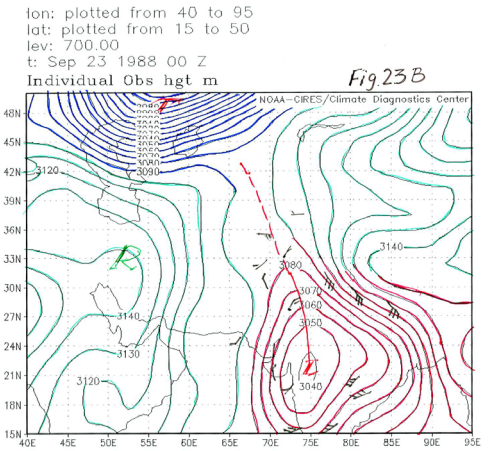
Figure 1: Track

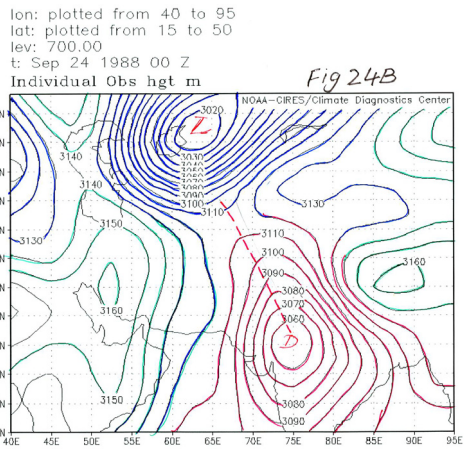
The track of the LPS when it first appeared on the surface chart of 23rd over Gujrat and its subsequent movement North words is as indicated in the Figure 1.

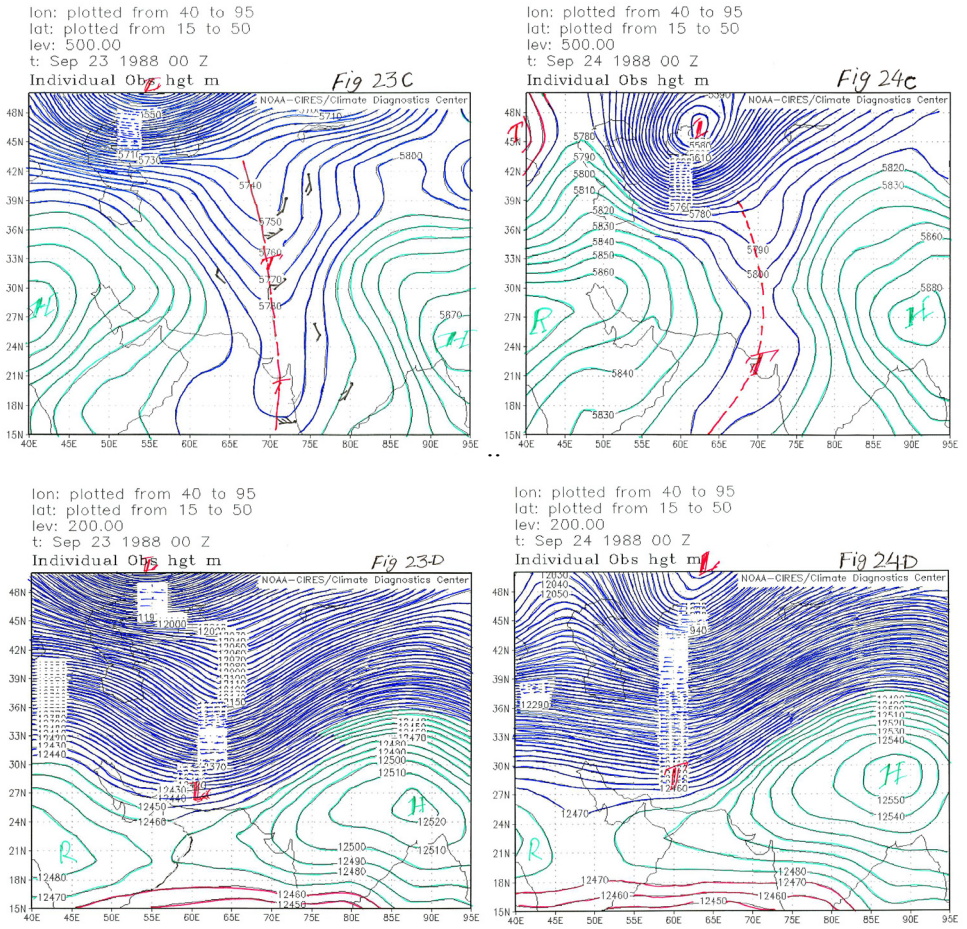
The LPS got accentuated upon reaching Rajasthan on 25th September. The further movement of the LPS did not occur on the surface level and instead an upper air cyclonic circulation developed far to the north over Kashmir due to strong SW flow caused by the strong westerly trough at 500 mb and above as shown in Figure 23 (A-D) and Figs 24 (A-D).



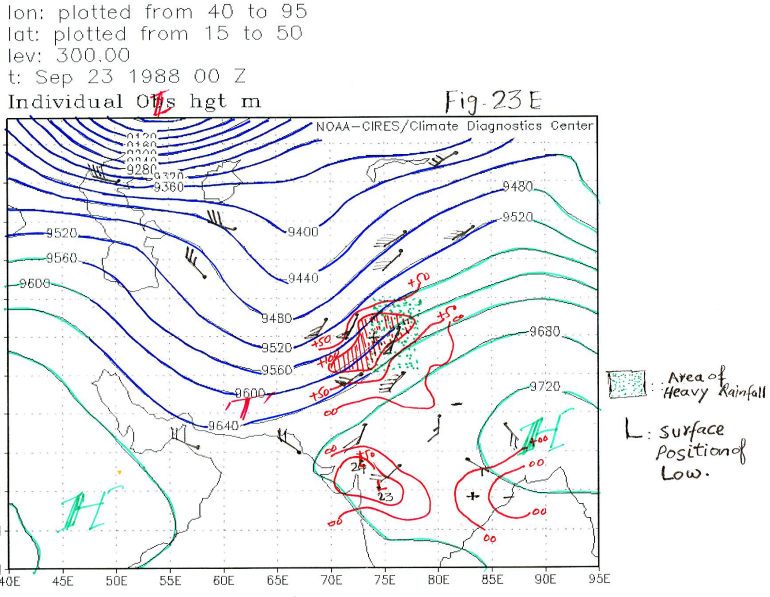








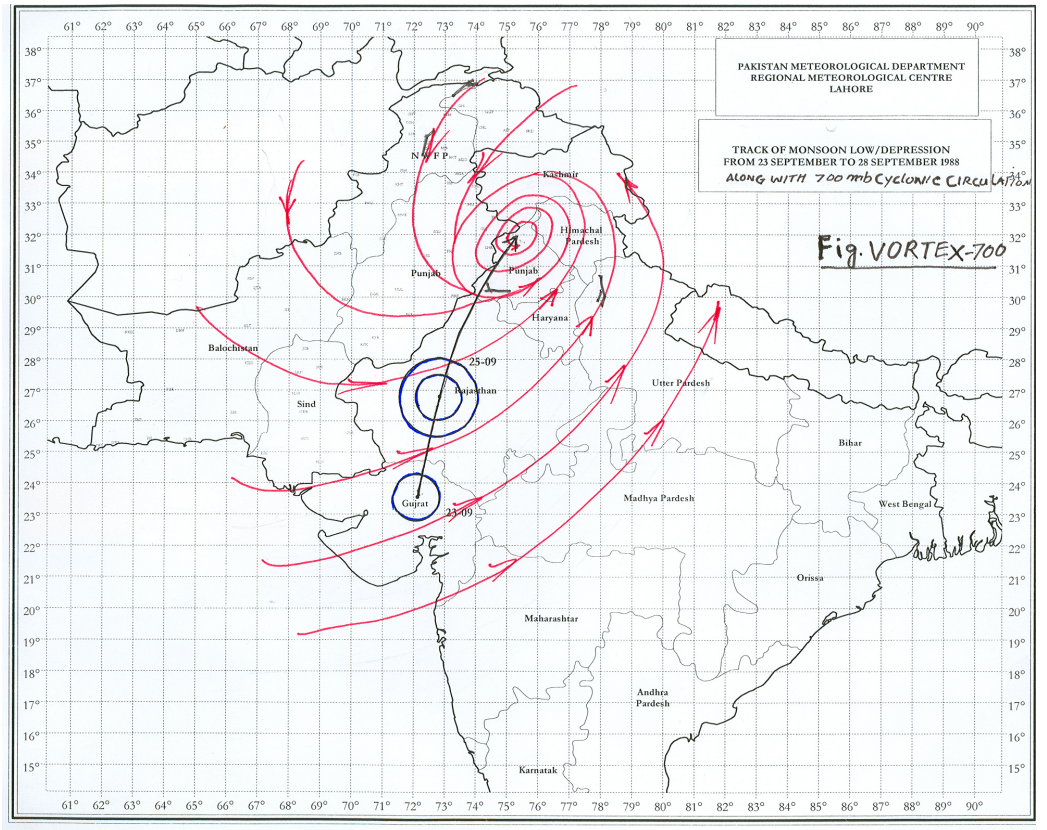
The Fig 23 E shown below indicates the westerly trough at 300 mb level. The rainfall



area in relation to the water vapour flux divergence (K. Parasad-1992) is shown on this figure in terms of divergence values (isopleths are shown in red colour). The positive values indicate convergence as explained here under.

Divergence is defined as the inflow – outflow (difference of inflow and outflow). In case of diverging field this value shall bear a negative sign. However, in case inflow exceeds outflow, the net result shall be positive i.e. it shall be a positive divergence which shall then indicate convergence. Thus convergence shall occur when the values of divergence at any point on the grid shall have the positive sign.

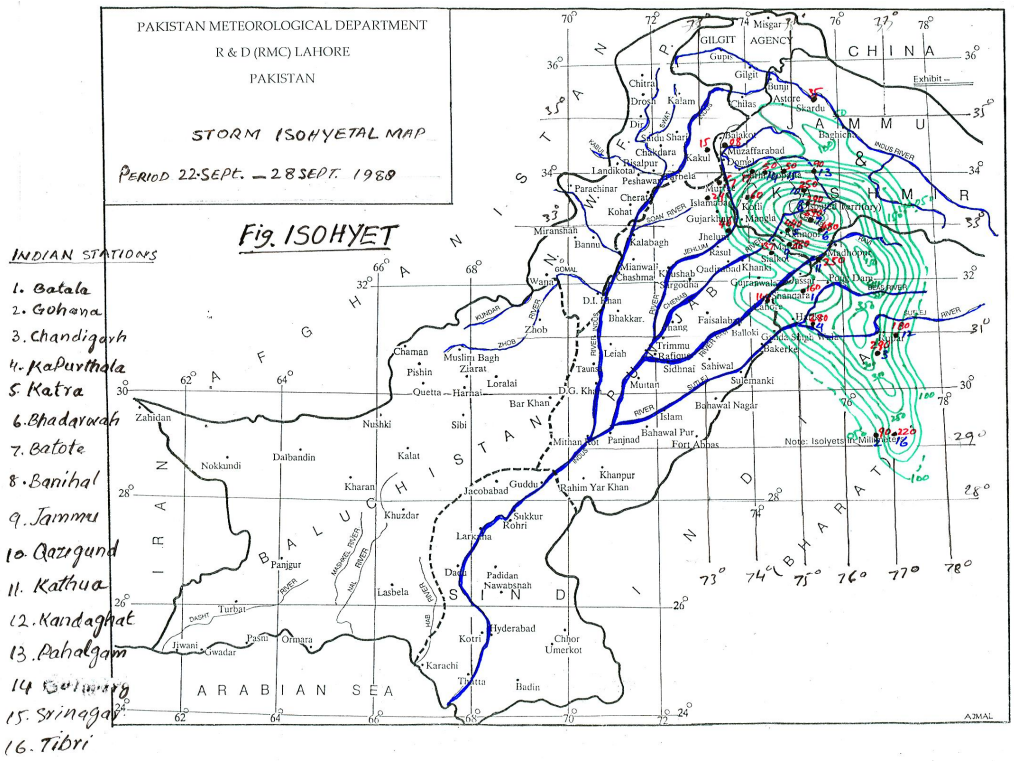
The formation and intensification of the westerly trough is due to the flanking effect of the two high's to the east and west of the trough position, especially at 500 mb. The position of the cyclonic vortex on 700 mb level is shown in Fig. vortex 700.



The LPS on surface remained stay put over Rajasthan while extremely heavy rain started over the upper catchments of Sutlej, Bias, Ravi and Chenab rivers across the border in India.

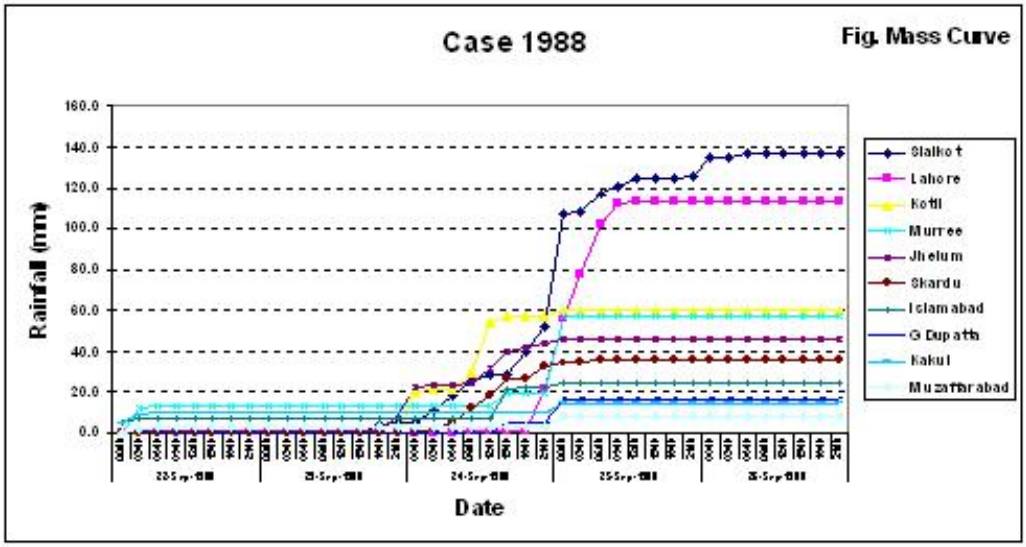
Pattern of the Rainfall Distribution:

Rainfall mainly occurred on 23rd and 24th. Rainfall centroid was close to the place called Batote in southern Kashmir as shown in the storm Isohyetal map at Fig. Isohyet.



The Indian and Pakistani Rainfall data is given in the table at annex A & B.

A secondary rainfall centroid could be located over the upper catchment of Bias River. The rain was later recorded in Pakistan over Sialkot and Lahore observatories as shown in the mass curves given at Fig. mass curve. Rainfall at Islamabad, Murree, Jhelum etc. is relatively insignificant.



The duration of the peak rainfall period is estimated to range from 0200 hrs on 24th September to about 2300 hrs on 24th September. Thus around 20 hrs is the period of the heaviest spell. The heaviest 24 hrs rain amounted to 320 mm at Batote in Kashmir (India).

Flood Situation:

The meteorological situation described earlier gave rise to one of the biggest historic flood termed as super flood by the Irrigation Department in the river Sutlej 4 lac Cusecs on September 30 at 1200 hrs at Sulemanki. Flood in Chenab crossed beyond 7.51 lac cusecs on September 25 on 1800hrs at Marala. Ravi got its share of flood which went unmeasured at Jassar as the discharge site was washed away and the duty personals ran for their life. The highest flood values recorded at Sulemanki and Marala for the river Sutlej and Chenab stood at 04 lac & 7.51 lac respectively. The discharge hydrograph for Sulemanki, Marala and Shahdra are given at Fig. Hydrograph.

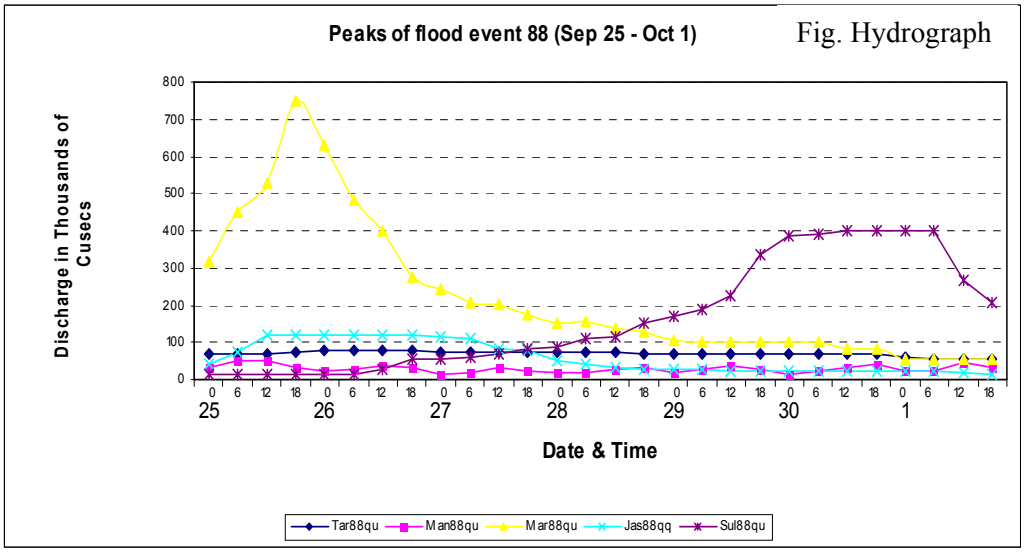


Fig. Hydrograph

Thus this was an unlucky case in which the timely flood warning by PMD was not actioned, resulting in the tremendous loss of life and property which could have been saved by the timely mitigation action. Cause of the heavy down pour over Kashmir was the large northwards movement of the upper tropospheric cyclonic circulation associates with the LPS. Under the effect of the strong westerly trough which resulted in the strong moisture incursion from the Arabian Sea.

Inferences:

Generally, the flood generating tropical depressions originate in the Bay of Bengal region. There are however cases wherein the LPS may originate over the ET at around 20° N in the area south of Gujrat state of India under suitable conditions of temperature, moisture and thermal instability. This process of cyclogenesis shall be facilitated by the upper air westerly trough at 500 mb and above.

The second most important impact of the westerly trough is to cause the north/northeastwards movement of the LPS since steering mechanism is dominated by the (700 mb – 400 mb) flow. In case the intensity of the LPS does nit exceed that of a deep depression (in case of the higher intensity LPS the steering mechanism is provided by the 200 mb wind flow). By the time the tropical LPS arrives at around Rajasthan region, its intensity is reduced to that of a deep depression only and thus (as in this case of 1988 flood event) the duration and speed of the movement of the depression shall be dominated by the wind field prevailing between 700 mb – 400 mb. Strong east/southeast flow shall be generated at these levels in case a westerly trough arrives immediately to the west of the surface position of the LPS (at around 70° E)

The recurving process is routinely caused by the presence of Tibetan anticyclone, which tends to move the severe cyclonic storms under its wind field at 500 mb and above.

The intensification of the LPS may occur due to the approach of the westerly trough (west of the surface position of the LPS) due to the advection of the warmer air to the west of the LPS. However the exact manner in which the intensification occur is not clear and calls for much more detailed investigation.

The approaching westerly trough tends to cause strong sheering effect in the wind field at the mid tropospheric levels (700 mb – 400 mb). This creates a strong cyclonic vortex at mid tropospheric levels and causes the northwards extension of the precipitation region.

The area ahead of the westerly trough is associated with the positive vorticity advection (PVA) and divergence. Divergence aloft causes low level convergence. The two factors together create strong rain producing situation.

The parameter closely related to the rainfall (in space and intensity) shall be the vertically integrated horizontal water vapour flux divergence values. Area of the higher (positive) values shall be the area of expected rainfall.

The region of the maximum rainfall shall be far to the north/northeast (around 600 km - 700 km) as compared to the surface position of the LPS.

The rain may continue even after the moving away (east wards) of the upper air westerly trough due to the sustained low level cyclonic circulation.

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FLOOD EVENT 1988 **Annex A**

22 - 27 SEPTEMBER 1988 RAINFALL DATA OF RELATED INDIAN STATIONS

Sr. No.	City	Region	Lat	Long	Elev Ft.	Rainfall (mm)						
						22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	Total Rain
1	Batala	State of Punjab	31.82	75.20	816	0	100	0	0	60	0	160
2	Gohana	State of Haryana	29.13	76.70	738	0	90	0	0	0	0	90
3	Chandigarh	Chandigarh	30.74	76.79	1053	0	0	190	0	0	100	290
4	Kapurthala	State of Punjab	31.38	75.38	738	0	0	280	0	0	0	280
5	Katra	State of Jammu and Kashmir	32.98	74.95	2473	60	0	90	290	0	0	**440**
6	Bhaderwah	State of Jammu and Kashmir	32.98	75.72	5295	0	0	160	160	160	0	**480**
7	Batote	State of Jammu and Kashmir	33.10	75.32	6584	0	0	150	320	120	0	**590**
8	Banihal	State of Jammu and Kashmir	33.42	75.20	5465	0	0	80	150	60	0	290
9	Jammu	State of Jammu and Kashmir	32.73	74.87	1072	0	0	70	270	40	0	380
10	Qaziqund	State of Jammu and Kashmir	33.63	75.15	5478	0	0	50	150	50	0	250
11	Kathua	State of Jammu and Kashmir	32.37	75.52	1007	0	0	0	250	0	0	250
12	Kandaghat		30.98	77.12	5216	0	0	0	180	0	0	180
13	Pahalgam	State of Jammu and Kashmir	34.03	75.33	8989	0	0	0	90	0	0	90
14	Gulmarg	State of Jammu and Kashmir	34.05	74.38	8825	0	0	0	50	0	0	50
15	Srinagar	State of Jammu and Kashmir	34.08	74.82	5101	0	0	0	50	0	0	50
16	Tibri	State of Haryana	29.12	77.03	721	0	0	0	0	220	0	220

FLOOD EVENT 1988 Annex B

22 - 27 SEPTEMBER 1988 RAINFALL DATA OF RELATED PAKISTANI STATIONS

Sr. No.	City	Region	Lat	Long	Elev Ft.	Rainfall (mm)						
						22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	Total Rain
1	Sialkot	Punjab	32.30	74.32	830	0	0	11.5	96.7	27.1	1.3	136.6
2	Jhelum	Punjab	32.56	73.44	767	7.1	Tr	16.4	22.8	0	0	46.3
3	Kotli	A.Z Kashmir	33.31	73.54	2016	Tr	Tr	21.3	38.8	0	0	60.1
4	Lahore	Punjab	31.33	77.20	702	Tr	0	0.2	76.9	36.4	0.3	113.8
5	Kakul	NWFP	34.11	73.16	4301	9.8	1.2	Tr	4	0	0	15
6	M. Abad	A.Z Kashmir	34.22	73.29	2303	2	1	0	5.3	0	0	8.3
7	Murree	Punjab	33.55	73.23	6974	15	0.5	0.2	41.8	0	0	57.8
8	Islamabad	Capital Area	33.37	73.06	1667	7	0	0	17.3	0	0	24.3
9	Skardu	Northern Areas	35.18	75.41	7250	0	0	2.3	32.6	0.5	0	35.4
10	G. Dopata	A.Z Kashmir	34.13	73.37	2664	3	0.3	0	14.1	0	0	17.4