Case Study: Heavy Rainfall Event over Lai Nullah Catchment Area

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Abstract

This research is an effort to understand the heavy rainfall phenomenon which gripped the upper area of Pakistan from 4–9 July 2008. This week lasting event created close to flood situation in Lai Nullah basin of Islamabad. The focus is mainly kept at flooding occurred in the Nullah on 5th July. This study was also an effort to effectively forecast the amount of precipitation expected as a result of such event so that flood like situation can be timely forecasted. The NCEP reanalysis (2.5° × 2.5°) data sets were utilized for this purpose. Different meteorological fields were used to get a picture of atmosphere. It also helped in comparison of both the observed and reanalysis data sets for one particular event. NCEP reanalysis data set though of coarse resolution presented good picture of event in terms of interaction between two main weather systems. The analysis revealed that the south-easterly incursion from the Arabian Sea was activated due to the westerly trough approaching the HKH mountain ranges. The results showed that Vertical wind Velocity (omega) and constant pressure surfaces are good predictors for this particular study.

Keywords: Lai Nullah, NCEP reanalysis, Arabian Sea, South-easterly.

Introduction

Pakistan being situated between 23° 35' – 37° 05' North latitude and 60° 50' -77° 50’ East longitude falls in the Extratropics. It defines the western limits of Easterlies in South Asia. Precipitation is received in both summer and winter seasons. Western Disturbances (WD) approaches the upper parts of the country throughout the year; while Easterlies are dominant only in summer. Both the systems sometimes overlap to extract a heavy downpour for the study area (Lai Nullah Basin).The lofty Himalayas, Karakoram and Hindukush (HKH) mountains play their role to provide orographic lifting to the weather systems.

The Micro and meso-scale low pressure vortices are formed generally in the western side of 850 E as a result of extended southerly troughs. They have a short life span and sometime produce heavy downpours [5].

Islamabad and Rawalpindi are situated along the Margallah hills. In this paper severe rainfall spell 4-9 July 2008 is analyzed. Our main focus is the flooding which occurred on 5th July due to 104mm rainfall received in only 100 minutes; 162 mm rainfall was recorded only in 5 hours at PMD Headquarters Islamabad. Densely populated low lying areas along Lai Nullah faced flood like situation causing massive destruction of property and life. Three people died in the flash flood. It was the heaviest short period rainfall in last six years, reminding the cloud burst of 23rd July 2001. Temporal coincidence of July 2001 and July 2008 shows that both the events occurred between 00-09 UTC.

Main tributaries of Lai Nullah start from the foot of Margallah Hills. Water from Islamabad piles up into a single stream and flows through the densely populated areas of Rawalpindi. The Basin area is approximately 240 Km², out of which 38.6 % residential. Length of Nullah is about 30 Km [7]. Accelerated urbanization and population growth minimize the water oozing lands and enhance aerosol concentration in the area. The banks of the Lai Nullah could not be identified (due to encroachment) and flow at its middle attains 30 km/h speed in general [11].

Rasul et al (2004) revealed the facts about the deflected monsoon currents that played an enormous role for heavy downpour in the Lai Nullah Basin in 2001 [11]. The purpose of our study is to describe the atmospheric condition instigated by southern moisture flux which became responsible for severe flooding

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in the study area on 5th July, 2008. The precise forecast can save loss of valued lives and economical damage of infrastructure in the civic population.

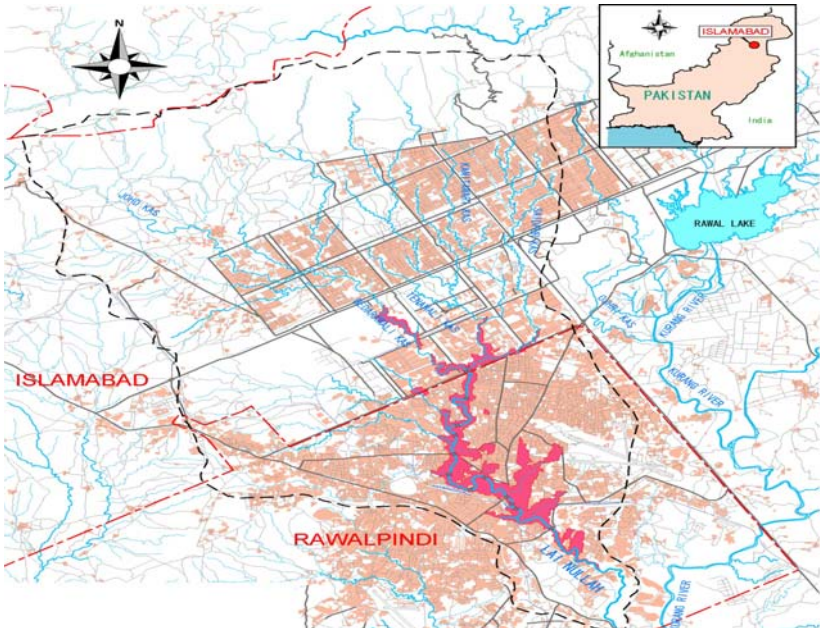

Figure 1: Lai Nullah Basin

Data & Software

* Observed rainfall is taken from PMD is plotted in excel worksheets.
* NCEP (National Center for Environmental Prediction) Data of spatial resolution of (2.5ox2.5o) reanalyzed to study the particular phenomenon. The temporal resolution of data is Six hourly.
* GrADS (Grid Analysis & Display System) help is taken in to account & NCEP gridded data is shown in the form of images. Horizontal and vertical picture of atmosphere is made by using different meteorological parameters.
* Diagrams displaying amounts of precipitation are the plotted by using Surfer soft ware.

Results and Discussion

The data has been studied to investigate the event. Following are the favourable weather parameters which caused the severe thunderstorm activity.

(a) Temperature

Low level heating in tropics plays key role for mesoscale and microscale convective phenomena. The surface heating raised the temperature of Lai Nullah basin up to 42oC on 4th July, 12z (Fig.2a). Temperature remained up to 34oC during the whole preceding time of event even after radiation cooling over night (Figure.2b& 2c). Seasonal low over Balochistan accentuated and displaced towards west. At 200hpa Tibetan plateau warmer than surroundings caused more moisture transportation from lower troposphere [1].Lower level heating and upper level support ultimately became clear evidence for uplifting mechanism.

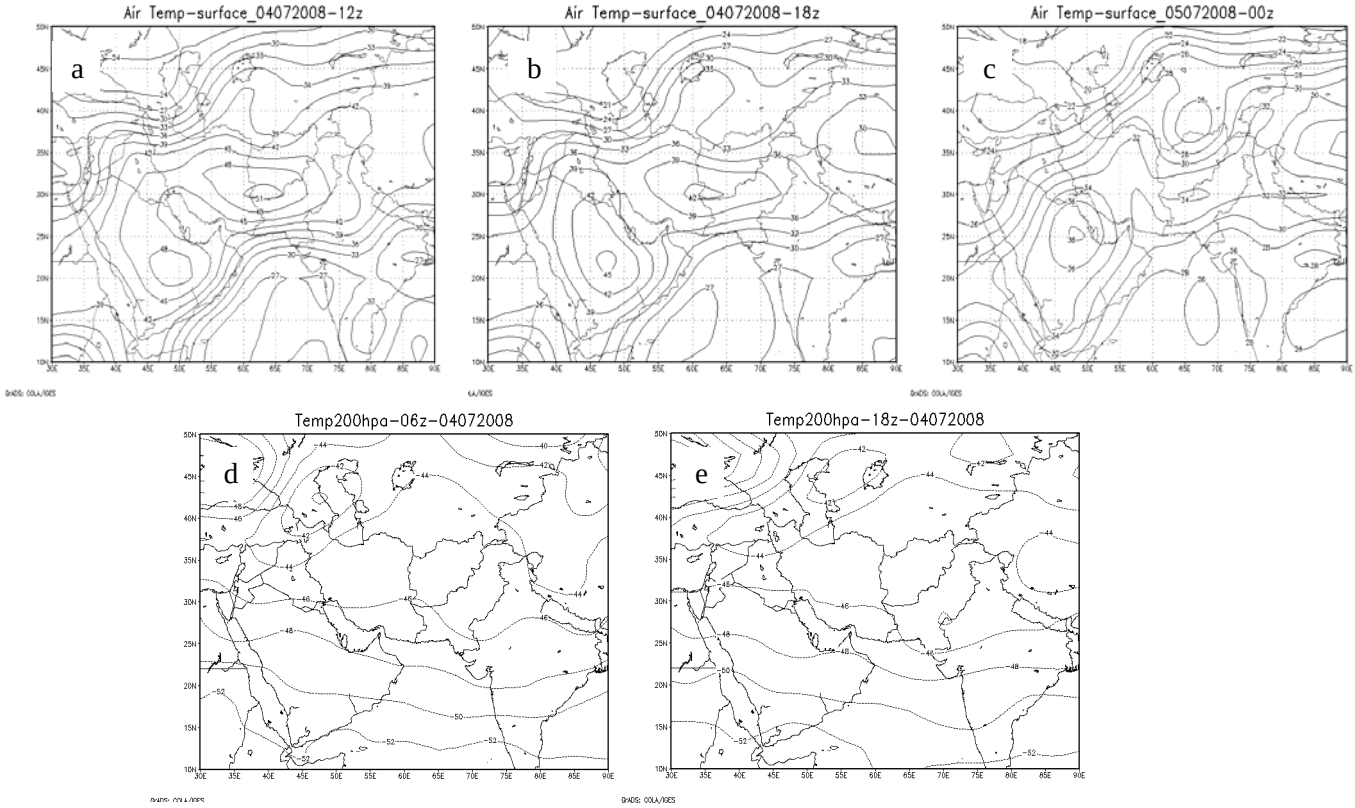

Figure 2: Temperature, Surface & Upperair

(b) Pressure & Geopotential Height

Synoptic chart for 00UTC analyzed at National Weather Forecasting Center gave a good picture of low pressure over the sub-humid mountainous zone. The low pressure cell was also present over southern Punjab along with the main Seasonal low over Balochistan. These lows caused constant moisture feeding in the lower troposphere. Southerly and south easterly currents remained on the go (Fig.3d).

It is evident by reviewing daily observed data at PMD that no much heating occurred in 2008, the heat low over Balochistan could not deepenn but Western Disturbances remained active through out the year.

The same occurred on 5th July event when at mid troposphere level (500hpa) an upper air westerly trough penetrated northern parts of Pakistan. Westerly trough gave cooling effect to the warm-moist air beneath and behaved as a triggering agent to extract the moisture from monsoonal currents. The Westerly trough became prominent on 00UTC, 5th July. Figure.3 (a-d) shows the constant advancement and penetration of the westerly trough over the foot of Marghalla hills. The orientation of westerly made an adequate cold air advection from higher latitudes to the upper parts of country. After the heavy rainfall (at 06UTC) high, pushing the westerly trough to the higher latitudes, dominated and gripped the entire Pakistan, Kashmir and north-western part of India. The contour 5880 (gpm) remained a constant cold air supplier for the lower atmospheric monsoon winds throughout the week. The similar short period patterns remained rainfall contributor up to 9th July, 2008. Yet the rigorous condition was the first episode of the spell, which is 5th July morning.

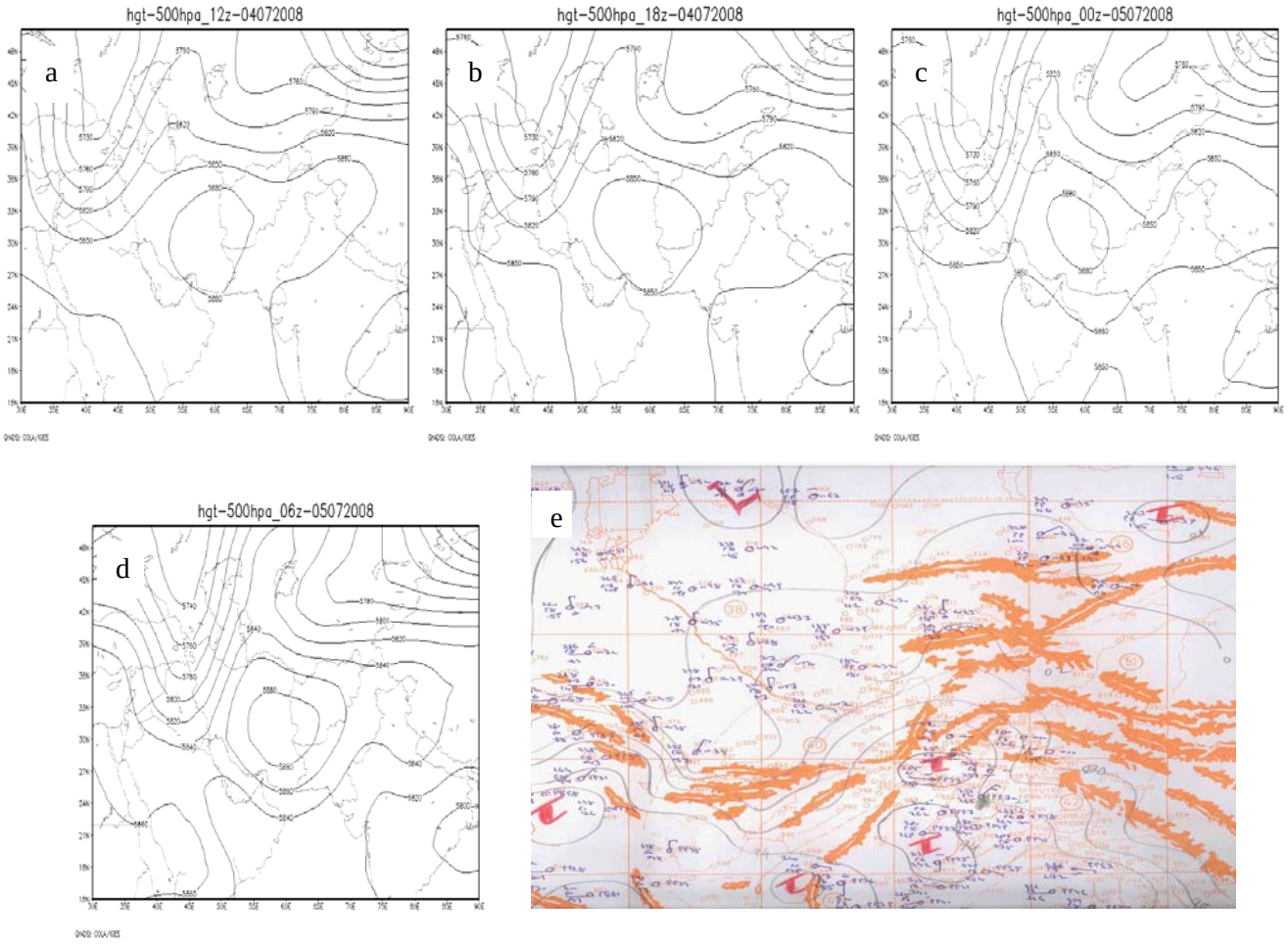

Figure 3: Surface Chart of 00UTC 5th July and Upper air CP Charts

(c) Winds and Moisture flux

The accumulation of moisture occurred along the foot hills of Himalayas due to constant currents approaching from Arabian Sea. Generally wind takes 12 to 18 hours from Arabian Sea to reach the study area.The streamline pattern for 850hPa shows the continuous moisture supply from the Arabian Sea. The stream line flow from south to north remained steady from 3rd July afternoon to the morning of 5th July (Fig.4.a-c). Thus sufficient moisture accumulated over the northern areas of Pakistan before the occurrence of flashy rainfall.

Figure 4(d-f) is clearly showing the invasion of westerly trough at 500hpa level. It remained dominant over the study area from evening of the preceding day (4th July) and persisted up to the morning of the day of episode. The bubble high appearing in figure 4-f is the result of light downdraft producing 2mm of precipitation before occurrence of the main event.

The wind flow at 200hpa level became favorable about 18-24 hours before the major downdraft. Figure4-g shows that divergence started from morning of 4th July and gradually shifted towards east. Due to this strong divergence the surface convection became vigorous and vertical transport of moisture drift enhanced from the lower troposphere [13].

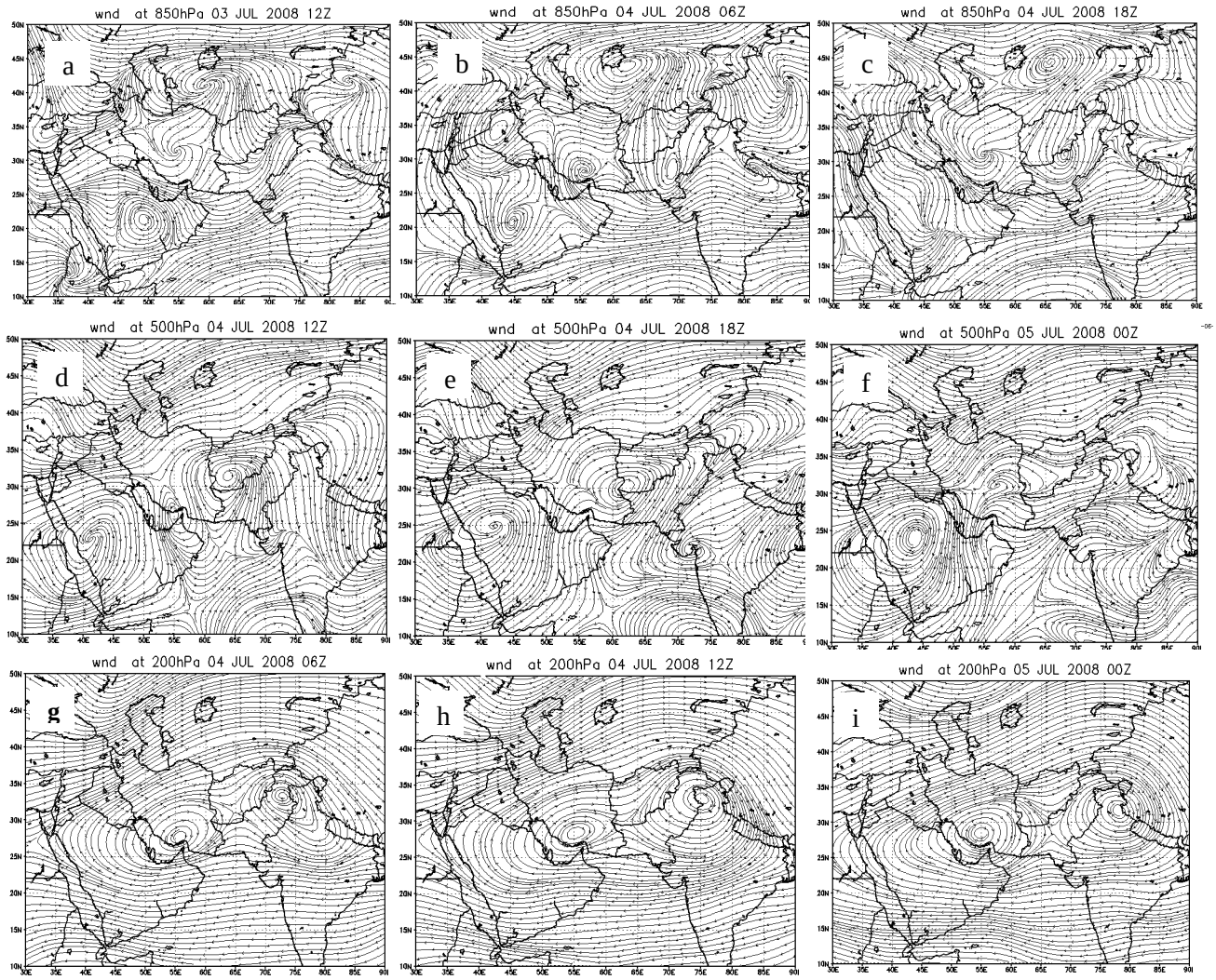

Figure 4: Stream line field on 4-5 July,2008 at (a-c) 850hpa, (d-f) at 500hpa& (g-i) at 200hpa

The moisture reaching the north made the area humid, The figure 5(a-b) shows that the northern Pakistan and north-western India along the great Himalayas are rich in moisture. Hot and dry air advection over the central Punjab from the west which caused the low relative humidity over there. But in the morning of 5th July (Fig.5-c) the whole of the above said areas enriched in humidity. A critical look shows that the increased humidity along the Himalayas is well defined in terms of streamlines over 850hpa (Fig.4 a-c). This moisture made the air lighter and the orographic lifting supported the vertical wind flow.

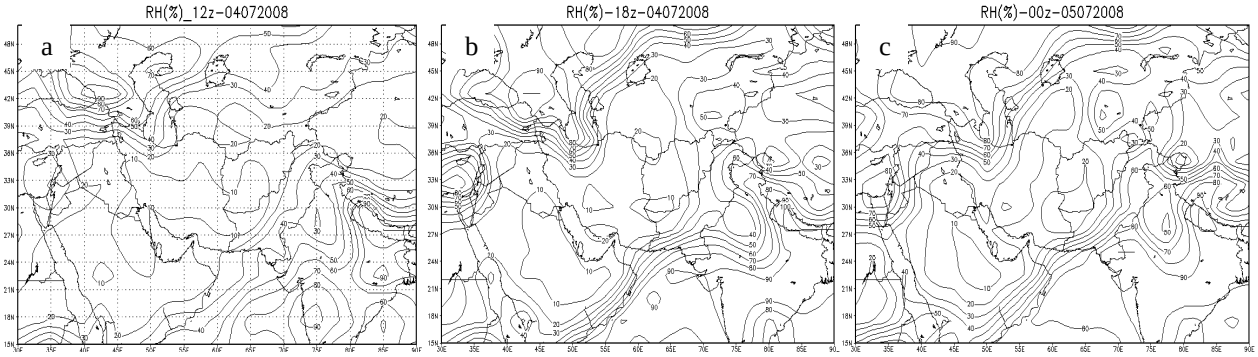

Figure 5: Relative Humidity (%) at Surface

(d)Vertical Profile and Instability

The winds are plotted in the form of vertical streamlines by fixing one graticule for a particular time. Fig 6(a-b) depict the vertical distribution of winds for 12UTC, 4th July. The moist air uplifting was up to 700hpa pressure level. The upper air divergence provided cold air aloft at 300hpa. So the cold air ceiling over the warm moist tropical air made the atmosphere unstable. The accumulation of moisture below provided the victuals for the system to develop gradually. Fig.6-c displays the isotachs along with the vertical streamline field. By fixing 33.4N, the maximum value of isotach is over 73E, at 850hPa over Lai Nullah catchment area (Fig6-c). The uplift of air remains active the whole night before even at 00UTC the convection remained without any restraint.

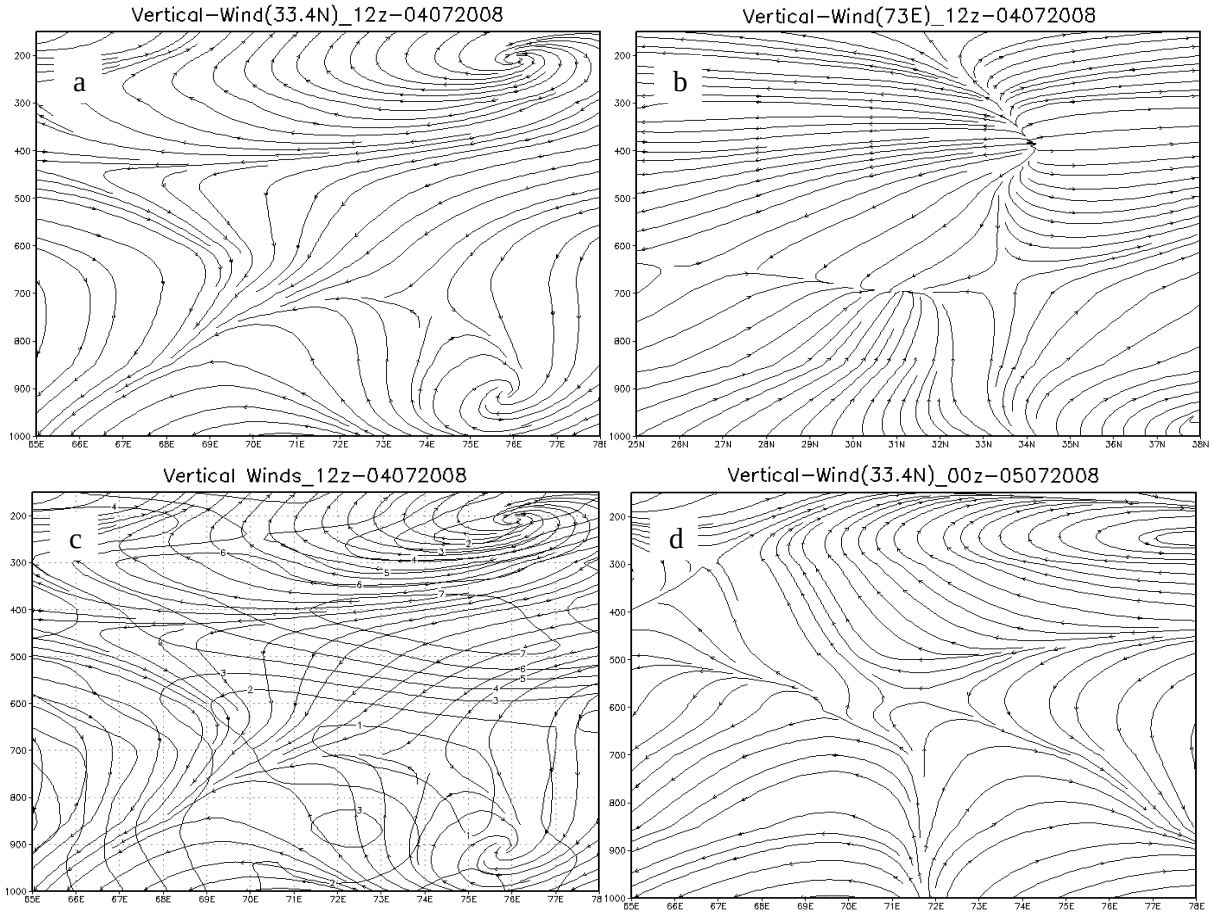

Figure 6: Vertical Stream-lines Flow

Vertical uplift near the surface became positive during night which is an evidence of strong uplift. Fig.7 (a-c) shows that over the study area the near surface winds were uplifting with greater thrust as the time for activity came nearer. Fig.7-d provides the information that the vertical velocity of moisture laden air is positive over the Lai Nullah Basin. Strong heating was the main reason for omega (hPa/Sec-1) to rise up to mid troposphere.

In Fig.7(e-f) Vertical profile for relative humidity is shown. Again very clear that as the time passed by the moist column of air floated in lower troposphere over the twin cities, Rawalpindi-Islamabad. The upper air very humid westerly can also be seen in the figure at 500hPa.

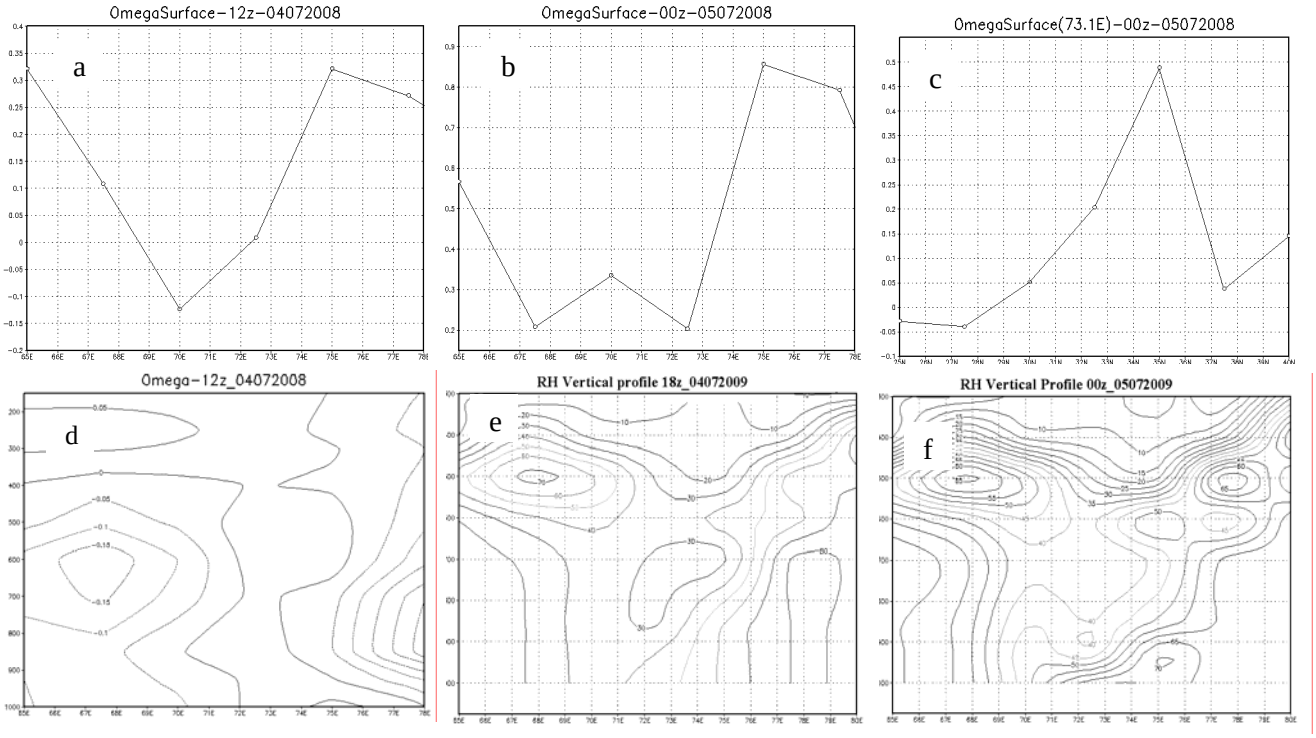

Figure 7: (a-d).Vertical Wind Velocities Omega (hPa/s) and ,(e-f) RH(%)

(e). Cloud Formation and Rainfall Mechanism

The vertical shooting of warm air made the cumuli-type clouds which resulted in to thunder storm (TS) activity. TS & heavy showers are the main features when a cold westerly joins the warm, moist monsoon air underneath. Generally Warm moist air is below the cold westerly so the absolute instable atmosphere produces to give severe output.

Main clouds which caused the activity on 5th July, 2008 were Cumulonimbus(Cb), Stratocumulus(Sc) and Altostratus(As). Mesoscale convective Cb two to three cells contributed to give 67mm and 104mm rainfall in successive turns. The Altostratus sheets enhanced the downpour. The flip-flop pattern of precipitation was due to As and Sc clouds. Two main spells were the outcomes from Cb mentioned in the table.1.

Table 1: Clouds, rainfall amount and wind

Sr. No.	Time UTC	Cloud Genera & Amount (octas)	Rain fall	Wind Speed (m/s)
1	1845-1935	Cb2, Sc3, As3	2.0 mm	Calm
2	0120-0205	Cb3, Sc2,As3	67.0 mm	SW-08
3	……..-0500	Cb3, Sc2,As4	104.0	calm

Sourc(NWFC, PMD)

The fig.8-a shows the rainfall amounts during the week when the westerly on and off penetrated the upper parts of the country gave rainfall. Whereas fig.8-b shows the real time rainfall calculated at Flood Forecast and easrly Warning System (FFWS), PMD, Islamabad. The rainfall received after 0300UTC on 5th July was reported on the next day

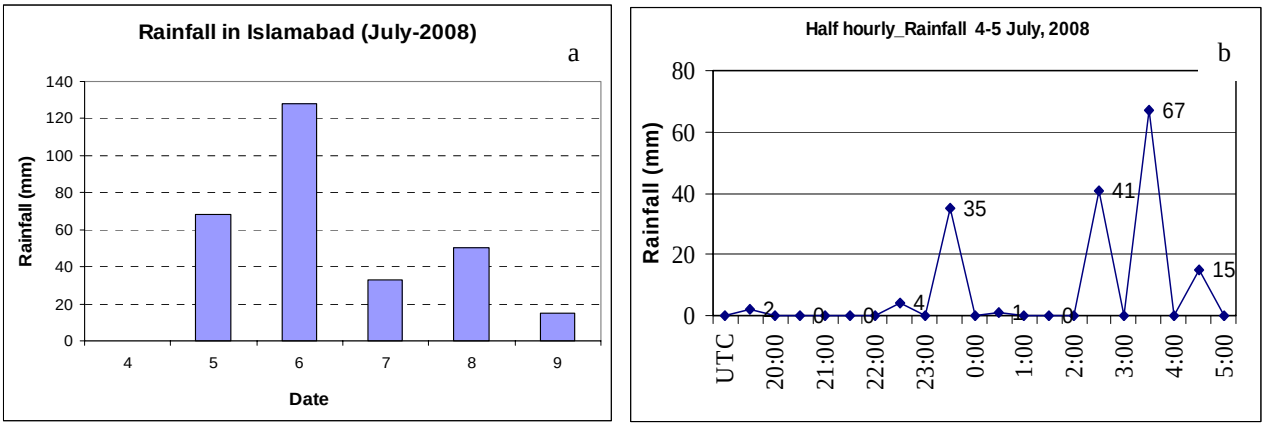

Figure 8: Rainfall (a). During week (b) Flooding event

Table 2: Rainfall in Islamabad 4-9 July, 2008

Date/Station	4	5	6	7	8	9	4-9 July	Normal July
AIRPORT	TR	26	82	60	13	24	205	305.3
DHAMIAL	0	0	38	86	26	20	170	…….
SAID PUR	0	30	20	44	40	5	139	……
SHAMSABAD	0	39	2	41	35	8	125	…….
PMD Headquarters	0	67	128	33	50	15	273	343.2

Sourc(NWFC, PMD)

Table 2 gives the rainfall amounts in (mm) of different stations installed in Lai Nullah catchment area. Raifall recorded in only five days was 205mm. It is greater than 60% of the monthly normal rainfall i.e. 343.2mm for PMD Headqurters. The normal rainfall for the month of July is shown in Fig.9 below.

Conclusion

In this paper sudden heavy showers of 128 mm in 24 hours over the Lai Nullah basin has been studied. This is the second heaviest downpour during the past hundred years. The relative weather elements have been analyzed to explore the consequences of this heavy rainfall event. Based on the analysis following conclusions have been drawn.

- The intensive heating over entire country and Arabian peninsula specially the presence of 510C isotherm over the junction of Iran, Pakistan and Afghanistan. This warm area moved eastward and penetrated to the northeast up to the study area uptill 00UTC of 5th July.
- The synoptic pressure pattern 00UTC of 5th July shows consecutive low pressure areas expanding from southwestern to the northern parts of the country. These lows supported each other to drift the moisture to the higher latitudes.

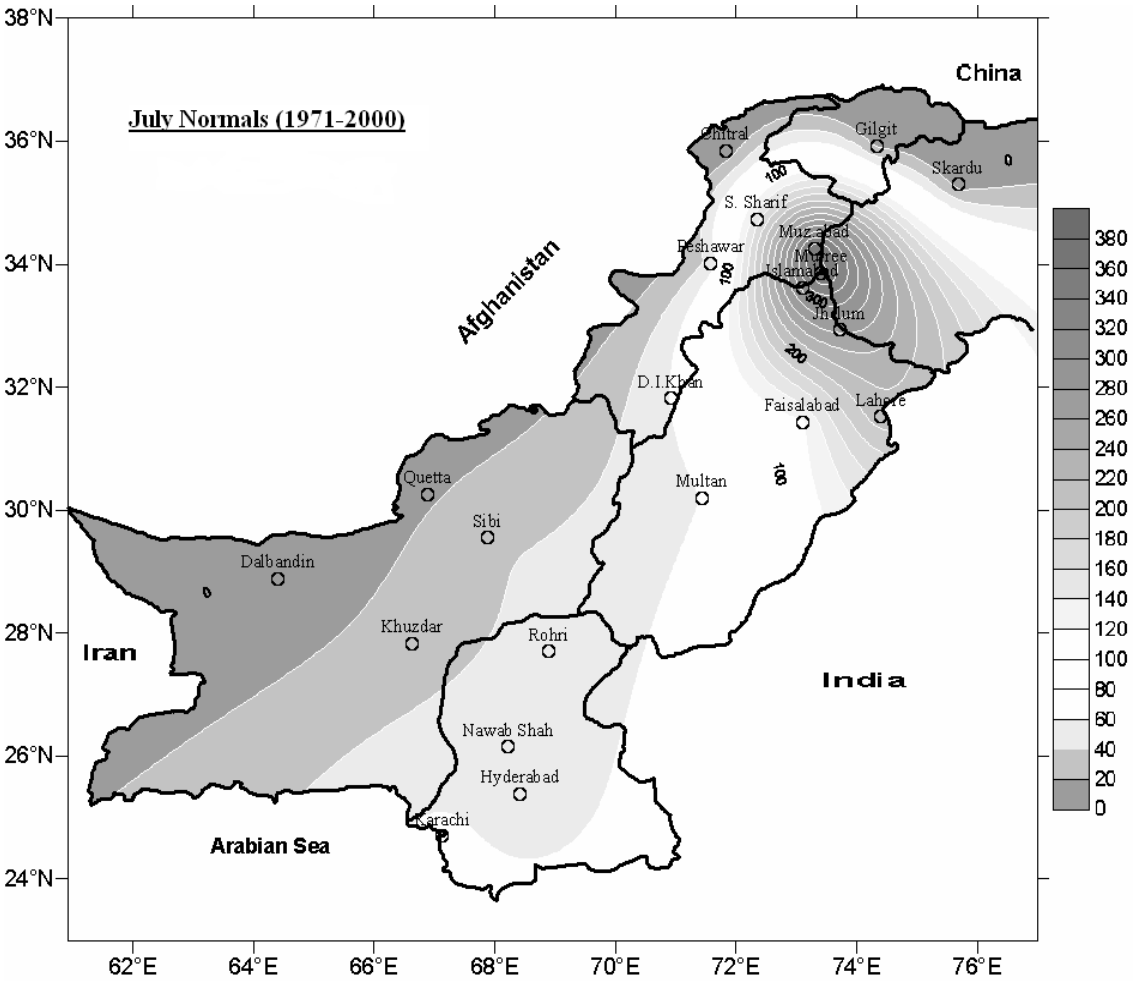

Figure 9: July Normal (1971-2000) rainfall(mm)

- The development of cyclonic vortex at 850hpa over Sindh-Balochistan region (06UTC4th July) and its movement to northwest centered over northwestern Balochistan providing sufficient racking for moisture flux from Arabian sea.
- Gradual displacement of subtropical high at 500hPa level let the westerly trough to penetrate over the Lai Nullah Basin.
- Strong divergence at 200hPa level exactly over the study area (06UTC,4th July) enhanced the lower tropospheric convection. The presence of strong divergence 18 to 24 hours prior to the even can be used as a good tool for precise forcasting of such heavy rainfall over the twin cties.
- RH has good equivalence to the streamline analysis that moisture coming from Arabian Sea accumulates along the foothills of Himalayas with great vertical extent.
- Vertical picture of preceding hours of main episode shows surface convection with sufficient vertical uplift and upper air cold advection.

Mesoscale systems are not prominently elaborated by NCEP reanalysis data due to coarse resolution. So for further studies, it is recommended that real time data sets availability may be assured particularly the radiosonde or rawinsonde data. Forecasters should have vigilant look in to the mechanism and precursors of such systems when superposition of westerly and monsoon currents takes place.

Acknowledgments

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