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MONSOON ONSET OVER SELECTED EASTERN BOUNDARY CITIES OF PAKISTAN

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Vagaries of monsoonal rainfall are the main cause of flooding in Pakistan which washed away standing crops in rural areas and damage the infrastructure of the cities. This study is an attempt to estimate, analyse and depict the monsoon onset characteristics over the eastern boundaries of Pakistan on the basis of available diurnal rainfall data for the period 1961-2010. For this aim pentad monsoonal rainfall calculation (in which total amount of rain should not be less than 20mm) with the condition of at least three days of rainfall employed. Early and delayed dates are also calculated for the said period of eight stations viz Lahore, Islamabad, Khanpur, Bahawalnagar, Rohri, Chhor, Sialkot and Bahawalpur. After standardizing the data, distance method is used to plot the contours. The results reveal mean dates of monsoon onset, ranges from the end of June (27th June) to start of August (1st August). As regards, delayed and earliest starting monsoon dates, it lying from 3rd of August to 17th of September and from 30th May to 25th of June respectively. It appears that delayed onset dates are rather scattered than the earliest ones. Findings of this paper may be helpful to the farmers, planners and forecasters of this discipline.

Keywords: Monsoon onset, Pentad rainfall, Earliest, Delayed onset.

1. Introduction

Agriculture is the mainstay of million of teeming population in Pakistan. Crops of the country predominantly dependent on natural rainfall and the most spectacular climatic event of agricultural relevance is the occurrence and commencement of the monsoon rains [1]. Defining and declaring onset of monsoon at a particular place is unequivocally important and difficult as it depends upon the interest in view. A synoptic meteorologist would declare onset based on prevailing airmass characteristics or synoptic situations. A hydrologist may prefer cumulative rainfall in a fixed period of time while an agriculturist would define onset based on distribution of rainfall.

The Pakistan Meteorological Department (PMD), however, till yet, declare dates of onset of summer monsoon with reference to the observations of monsoonal winds and decreased temperature from the torrid heat of clear summer months and surface winds having predominant westerly direction. The normal dates, thus, first seen in the eastern Punjab and gradually advances to the other parts of the country. Over the eastern Punjab areas monsoon onset is seen generally more or less on 1st of July [2]. By the end of July nearly the whole country except extreme west Baluchistan and Khyber Pakhtunkhwa covered by the monsoon.

A number of studies have been carried out for the monsoon onset over the Indo-Pak region at different places. Bhullar [3] studied dates of monsoon onset over Delhi based on 50 years data (1901-1950) and fixed mean date as 2nd July with a standard deviation of 7 to 8 days. Ananthakrishnan [4] concluded that onset dates as determined by Indian Meteorological Department is subjective. Subbaramayya and Bhanukumar [5] attempted to evolve a guiding principle for fixing onset dates by taking into consideration the significant changes in cloud amount, rainfall and temperature at the onset time. Ananthakrishnan and Soman [6], by superpose epoch analysis, were able to prove that a sharp and spectacular increase in daily rainfall heralds monsoon onset over Kerala.

As regards Pakistan, although some useful studies carried out [7-12] but in relevance of onset of monsoon till yet no study is attempted. The aim of the present study is the statistical estimation and examination of onset dates of monsoon over selected eastern boundary laying stations. It is also proposed to find out if these dates have any bearing to the seasonal rainfall.

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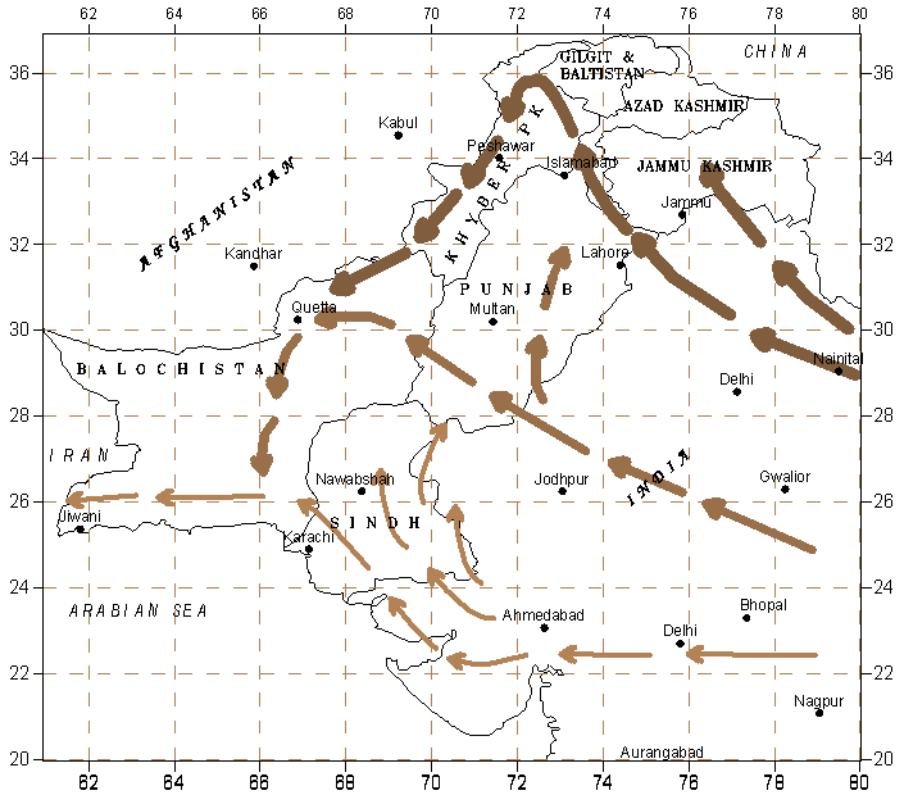

Figure 1. A schematic representation of monsoon flow into Pakistan, in terms of heavier and more frequent flows.

2. Data and Methodology

Monsoonal flow entered in Pakistan from the Indian side and may be divided into three prominent tracks (Fig. 1). Precipitation and cloud systems are frequently outcomes of the depressions in Bay of Bengal which locomote towards the inland areas of India along monsoonal trough. Their route toward Pakistan is dependent on Indian blocking ridge/high. Upper air dry/moist geo-potential charts of 850, 700 and 500 hpa are helpful to ascertain such blocking ridges/highs. Moreover, extent of low pressure and its intensity are also the factors on which rainy monsoon system reaching over Pakistan depends.

Infrared satellite images manifested the intensity of clouds' top as whiteness, pointing the temperatures of the cloudiness. As tropical factors governed the monsoon systems, top of the cloud is directly related to their height and thickness [13], which is successively declarative of the intensity and precipitation they provide. Hence, prominent white cloud in infra red satellite image during summer (April to October) invariably means precipitation over Pakistan [14]. Further, thickness of cloud may be confirmed by visible satellite day time images, in which whiteness of cloud is proportional to its thickness.

As brought out by the infrared and visible satellite images discussed above, in general, three tracks of large, heavily moisture-laden, low pressure systems invading Pakistan from the eastern border are on either of the following routes (Fig. 1).

a. Bengal-Punjab-Kashmir-Khyber Pukhtunkhwa Province
b. Orissa-Madhya Pradesh-Rajasthan to lower Punjab-upper Balochistan-Khyber Pukhtunkhwa province in Pakistan
c. Orissa-Madhya Pradesh-Gujarat-Kuch to Sindh and Balochistan.

Available meteorological stations viz Lahore, Islamabad, Khanpur, Bahawalnagar, Rohri, Chhor, Sialkot and Bahawalpur are selected because they cover all the three tracks mentioned above. Islamabad, Lahore and Sialkot lie on first track of upper latitudes. Khanpur, Bahawalnagar, and Bahawalpur are on middle track of middle latitudes of the country while Rohri and Chhor are located on lowest southern track.

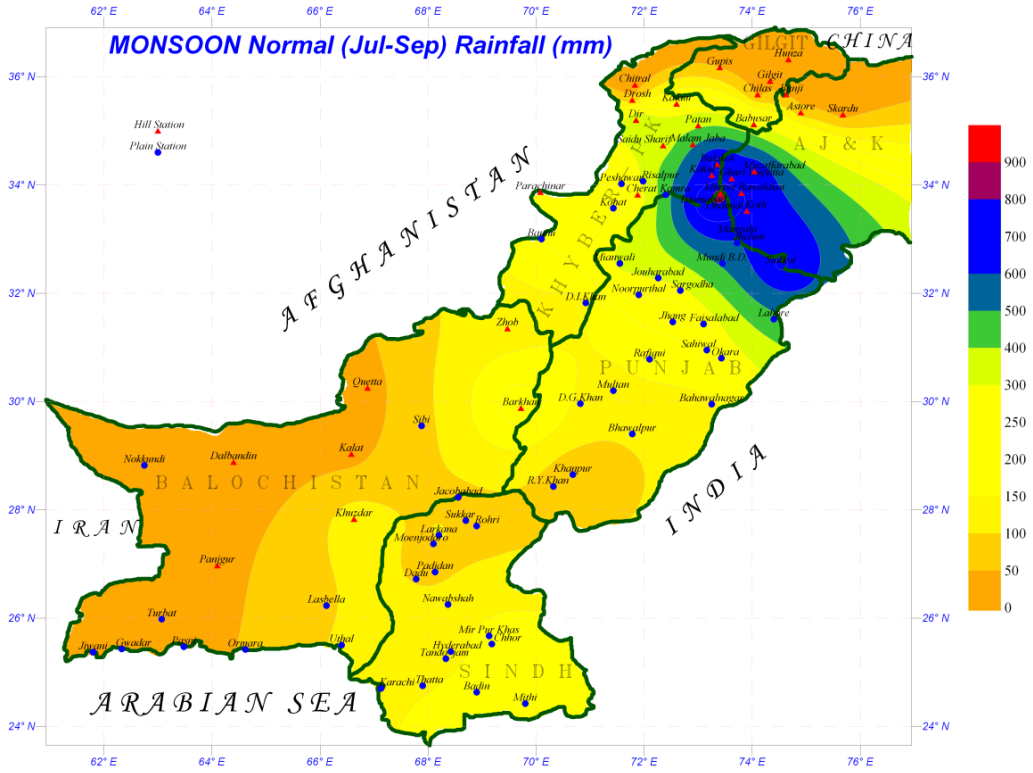

Figure 2. Normals of monsoon over Pakistan.

2.1. Normal Monsoon Synoptic Features

The monsoon season rainfall map (Fig. 2) shows highest rainfall area of more than 600mm is observed in Kashmir, adjoining sub-mountain areas of the Punjab and some eastern parts of the KPK [15]. It shows that these areas are mostly affected by the penetration of monsoon currents produced due to monsoon depressions/lows which moved west north westwards from Bay of Bengal. Extreme Southern parts of Punjab, Upper Sindh excluding Nawabshah, most parts of Baluchistan excluding northeastern parts receive less than 100mm of rainfall. Lower Sindh and adjoining southeastern parts of Baluchistan get affected by Mid-Tropospheric Cyclone (MTC) which develops over Saurashtra and Kutch and adjoining northeast Arabian Sea during monsoon season. The driest part is observed in northwestern parts of Baluchistan which is obviously not affected by monsoon.

2.2. Criteria for Monsoon Onset and Data Set

In fixing the date of onset of monsoon over different areas rainfall as a parameter has the over riding importance. However, exact quantification of rainfall for this purpose is rather difficult and hence experience of forecasters become useful. Factors such as clouds isobaric gradients, circulation features in lower and upper troposphere, etc serve as qualitative guide to the forecaster. Till yet no statistical criteria of monsoon onset have been determined by PMD, according to best of our knowledge it is the first attempt to set the monsoon onset dates by using panted rainfall. In this study following criteria has been adopted for fixing the date of monsoon onset for the cities under consideration. The first occasion after June 1, the 5-day accumulated rainfall should equal or exceed than 20 mm and it also includes at least 3 rainy days. The middle date of the 5-day period is taken as start on monsoon over the station. The extreme dates are considered as early and delayed insetting. In order to differentiate monsoon & pre-monsoon rainfall, synoptic features, such as isobaric gradients, tropospheric circulation, etc. have been individually inspected in the past several cases where onset dates were determined in earlier part of the season. The data for this study is taken from PMD archives which consist of daily rainfall data for 1961-2010.

Table 1. Some characterized statistical & analytical values for eastern boundary stations.

Parameter	Sialkot	Lahore	Islamabad	B.Nagar	Khanpur	B.Pur	Chhor	Rohri
Max Rain (mm)	216	192	226.90	154.40	172.7	71.10	165.20	128.40
St Dev	35.50	32.92	43.23	33.20	44.7	14.49	37.31	29.95
Q1	27.35	32.63	30.12	31.67	27.6	23.25	26.65	3
Q3	189.28	71.07	73	72.18	79	43.75	74.82	79.43
IQR	18.50	38.45	42.88	40.50	51.4	20.50	48.17	46.43

Analysis of 5-day rainfall for eight selected stations for the said period revealed that dates of onset determined by this method were within 2 days of those declared by Pakistan Met Deptt. in 60% and within 4 days within 80% of the cases studied. By and large, it may be said, the method of determining onset date by pentad rainfall gives a close picture of the actual onset over Pakistan.

3. Results and Discussion

3.1. Mean Date and its Variation

At first, number of rainy days and their deviation from the mean is enumerated and checked. Bahawalpur comes out with largest range (110 days) and deviation (26.83) in contrast to Sialkot shortest range (62 days) and deviation (12.81). Chhor, Rohri, and Lahore's range is in 70's while Islamabad, Bahawalnagar and Khanpur's range is in 80's. As regards deviation, Lahore (16.83), Islamabad (17.7), Chhor (17.05), are closer while Bahawalnagar is with little difference (19.83). Rest of the deviations lies in between 16.83 to 23.42. A few characterized statistical and analytical values are summarized in Table 1.

3.2. Data Standardization and Contours Formation

After deviation, data is standardized to make it useful for applying the distance method. To standardize an observation in population, population mean is subtracted from the observation of interest and divide the result by the population standard deviation. The product of these operations is the z-value associated with the observation of interest. It is used as method for ranking two observations to convert the individual observations into standard units known as z scores (or z values), which is an observation, x, from a population with mean μ and standard deviation σ, has a z score or z value defined by

$$z = \frac{x - \mu}{\sigma}$$

It measures how many standard deviations in an observation are above or below the mean. Since σ is never negative, a positive z score measures the number of standard deviations an observation is above the mean, and a negative z score gives the number of standard deviations an observation is below the mean. Note that the units of the denominator and the numerator of a z score cancel. Hence a z score is unit less, thereby permitting a comparison of two observations relative to their groups, measured in completely different units. After z score rainfall contours are drawn by using distance formula viz

$$D = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$

Where D = Distance, $\Delta x = x_2 - x_1$ and $\Delta y = y_2 - y_1$

Distance method with distance power two is used after standardizin and data. Finally contours have been drawn for eight selected stations (Fig. 3).

3.2.1. Track One

For Islamabad, heavy amounts of downpour are observed from end of July to start of August for 1960-1995, after which contour are absent; indicating decrease in amount of rainfall for this period. In Lahore, relatively heavy rainfall (>60mm) has been observed from 1962-1974 for the last ten days of July to starts of August. Similar pattern is observed for recent decade from the end of June to about end of July.

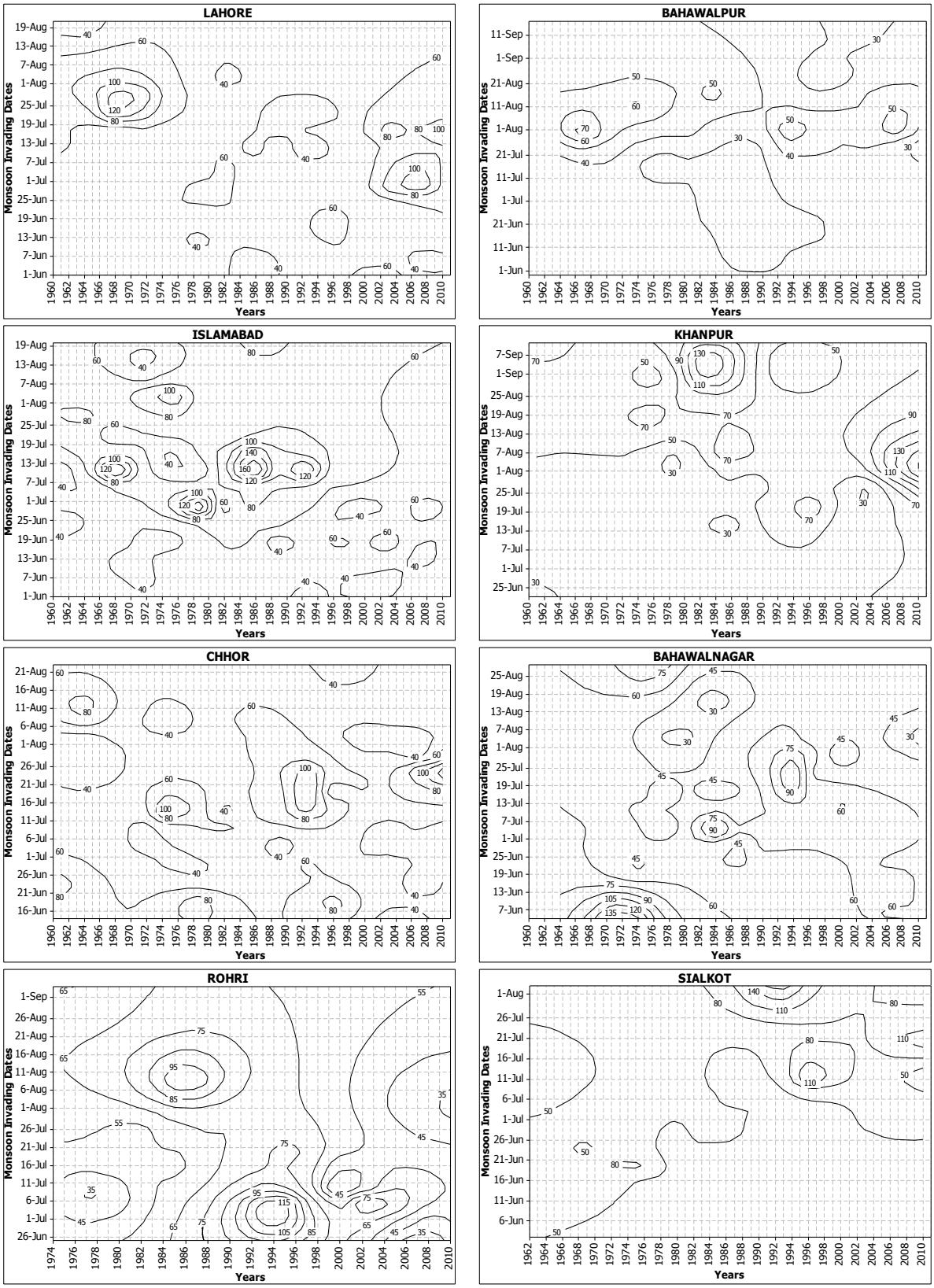

Figure 3. Rainfal contour plot for the 8 stations lie over eastern boundry of Pakistan.

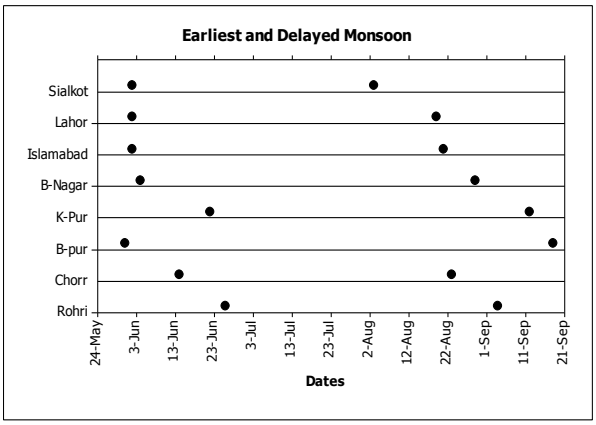

Figure 4. Earliest and Delayed dates of Monsoon

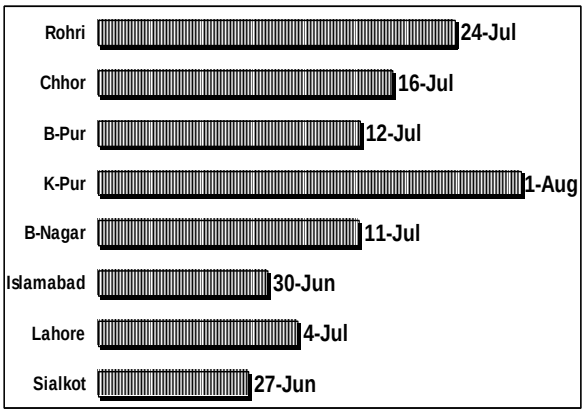

Figure 5. Mean onset dates of Monsoon.

It also implies the recession of heavy rainfall. For Sialkot a small contour appears in June in 70s but during 80s and mid of 90s heavy amount is seen for end of July and early days of August. In the last decade the pattern shows little scattered behavior in it but still remain from mid of July to starting of August.

3.2.2. Track Two

In the case of Bahawalnagar, a prominent (60mm) contour's accumulation is seen from 1963 to 1980 form start June to mid June. Two small patches are seen in July and rest of the contours are showing less than 60mm of rainfall. Overall there is less variation is seen in Bahawalpur while relatively heavy rainfall events seems from mid of July to end of August. As far as Khanpur is concerned, for the last decade, before 18th of July less than 50mm rainfall is recorded. Other closing contours are seen from 1974 to almost 1990 from 19th of August to onwards. The situation indicated that the extreme events are coming too early during the last decade. Overall, month of June shows the low rainfall contours throughout.

3.2.3. Track three:

Rainfall contours of Choor are somewhat scattered and does not indicate a definite symmetry or behavior. For Rohri, the heaviest and close accretion of contours is seen from 1987 to 1999 from the end of June to end of July. Another accumulation has its peak activity in mid of August for the 1980s. Recent decade shows relatively less values of rainfall which shows the rainfall amount goes below normal for last decade.

3.3. Earliest, Delayed and Mean Dates of Onset

Close observation of earliest and delayed dates of monsoon onset make visible that these dates covers almost June except a few last days and August with more than half month of September respectively; hence, July comes out with no significant role among these dates (Fig. 4).

Delayed starting monsoon dates seems rather scattered than the earliest ones; ranging from 3rd of August to 17th of September (Fig. 4). Lahore and Islamabad differs just for one day (i.e. 19th and 20th of August) whereas, 23rd of August is in closed proximity regarding Chhor. Sialkot appears with soonest (3rd Aug.) and Bahawalpur appears with latest (17th Sep.) among delayed dates. Bahawalnagar get delayed monsoon at the end of August (i.e. 29th of said month) while Rohri and Khanpur had seven days difference with 4th and 11th of September respectively.

In contrast to discoursed delayed dates above, most of the stations acquire earliest monsoon dates at close propinquity ranging from 30th May to 25th of June. Sialkot, Lahore, Islamabad, Bahawalnagar and Bahawalpur appear with even closer monsoon starting dates, i.e from 30th May to 4th of June (Fig. 4). Again Rohri and Khairpur have closed dates regarding earliest monsoon i.e. 22nd and 25th of June while Chhor is started at 14th of June. Comparatively Rohri and Khanpur are found closed i.e. 25th and 22nd June respectively. 14th June is found as the starting date for Chhor.

Mean dates of monsoon onset, ranges from the end of June (27th June) to start of August (1st August) (Fig. 5). Most delayed appear for Khanpur (1st August) followed by Rohri (24th July) whereas earliest is observed for Sialkot (27th June) prior to Islamabad (30th June). Among rest of the stations monsoon in Lahore starts in first decade of July (4th July) while Bahawalnagar and Bahawalpur have

very closed mean dates (11th & 12th July) with closer to Chhor (16th July) in second tenner of July.

4. Conclusion / Summary

The paper is first ever attempt in Pakistan to propose a methodology to determine the on set dates of monsoon, based on the analysis of fifty years of daily rainfall data of eight historical climatolgical locations viz Lahore, Islamabad, Khanpur, Bahawalnagar, Rohri, Chhor, Sialkot and Bahawalpur; situated on the eastern boundary of the country. Mean, early and delayed monsoon onset dates are estimated for these stations reveals that mean dates of monsoon onset are mainly falls in the month of July while early and delayed dates found in June and August respectively. It has also been observed from the analysis that normally monsoon first onset on areas of Sialkot and Islamabad. On the other hand it approached to the areas of Khanpur & Rohri with significant delay.

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