The Nucleus **49**, No. 4 (2012) 329-338

The Nucleus
A Quarterly Scientific Journal of Pakistan
Atomic Energy Commission
NCLEAM, ISSN 0029-5698

SPATIO-TEMPORAL ANALYSIS OF WESTERN DISTURBANCES OVER PAKISTAN

I. AHMAD and *N. SADIQ[1]

Pakistan Meteorological Department, Geophysical Center, Brewery Road, Quetta., Pakistan

[1]Institute of Space & Planetary Astrophysics, University of Karachi, Karachi, Pakistan

(Received September 27, 2012 and accepted in revised form December 07, 2012)

Considering the vital and unequivocal seasonal importance of western disturbance, it has been analyzed for the period 1973-2007. This study is appropriate to be based on annual, monthly, regional and seasonal investigation for the mentioned period. It is found that the total annual events and days (occurred during the events) are revaluing. The said intervals are also found apprising for the northern and northern plus central parts while considering the whole country, minifying trend is found. Maximum events & days occurred in summer whilst minimum during winter in the monthly analysis. However, the total monthly days and events for different regions show peculiar relations with each other. Seasonal study reveals increasing days and events for all seasons and the highest increase is found in Monsoon season. Further annual and monthly events and days are studied separately for each month through dot plots to observe the shifting pattern of western disturbances for every month. The study is represented through trend models, box plots, dot plots, time series and bar graphs.

Keywords: Monthly, Annual, Seasonal, Regional, Western disturbances

1. Introduction

Western Disturbances are the synoptic scale systems with associated clouding and precipitation patterns and which move from west to east/north-east from over Turkey, Iraq, Iran and Afghanistan over Pakistan and northern parts of India. These can also be referred to as the eastward moving upper air troughs in the subtropical westerlies, often extending down to the lower troposphere of the Pakistan and northern India latitudes [1]. These moving troughs often give rise to closed cyclonic circulations on Iran, Pakistan and northern parts of India during the winter months.

Although many studies have been carried out in respect of monsoon regarding Pakistan [2-6], but the analysis of western disturbances remain neglected while modest amount of rainfall and thunderstorms resulting in the wake of their passage over Pakistan is of vital agricultural importance [7]. The most important crops grown in this region depend, both for their sowing as well as harvesting, upon the timely winter rainfall in our areas [8]. Failure of winter rains put unbearable strains on the agriculture of the country. The behavior of most of the disturbances affecting Pakistan is very much similar to the behavior of the extra-tropical cyclones affecting middle latitudes [9]. The formation and the development of these disturbances can be traced as far in the west as the Mediterranean Sea.

Sometimes these depressions may have two centers after splitting [10]. The secondary is very intense which gives rain to southern parts of Pakistan (Sindh, Balochistan etc.) but as its formation is not that much frequent and it does not form throughout the year, Pakistan gets almost no rain in Sindh during the winter [11].

The situation in summer is somewhat simple. In the lower levels there are south westerlies over greater areas of south and east Asia [12]. These south-westerlies are curving cyclonically towards north / northwest at and from latitude 20° N. There is a component of the north-westerlies over Pakistan. At 6 km, the flow is essentially westerly north of the Himalayas whereas the easterlies dominate south of it [13]. Further sometimes, no frontal system is associated with westerlies due to lack of temperature gradient. It is simply low-pressure system, which moves from west to east but does not able to produce any kind of weather. The moisture supply is not there, however, the

* Corresponding author : nsadiq@uok.edu.pk

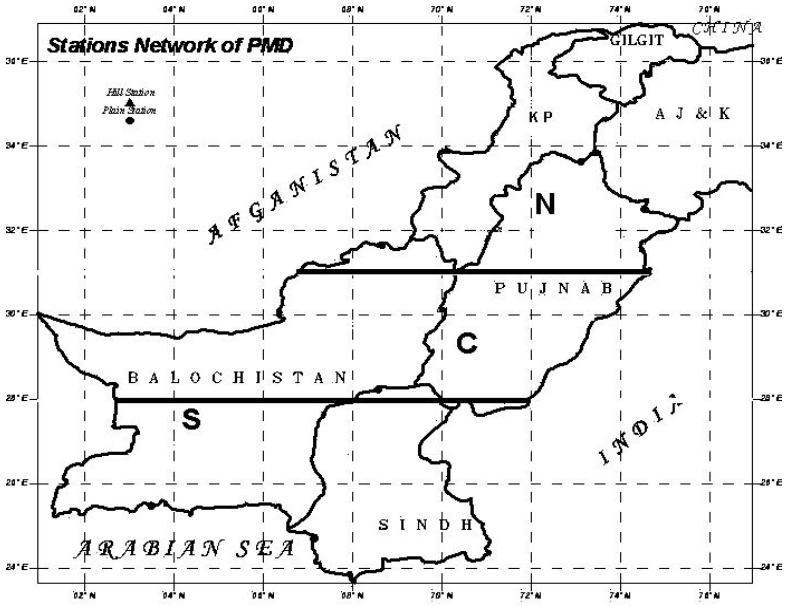

Figure 1. Map depicted the division of Pakistan into three regions/Parts i.e. N, N+C and N+C+S.

accentuation of the seasonal low occurs quite often on account of the arrival of westerly wave. The westerly wave due to the divergence aloft causes low level convergence above the seasonal low, resulting into its accentuation and thus weather occur.

As the role played by the western disturbances while passing over Pakistan are multidimensional and it will not be an exaggeration of the facts if concluded by saying that the agriculturally oriented economies of Pakistan is highly dependent on the favorable existence and eastward movement of western disturbances over country. This asks for the study of the events and days of the invading westerlies over different regions of Pakistan in different seasons and months.

2. Data and Methodology

The data available to used in this study comprises the events & days of western disturbances for the period 1973-2007. The data has been extracted from the observational records of the daily weather charts for 35 available years at Main Analysis Center (MAC) of Pakistan Meteorological Department, Karachi.

In winter, rainfall is considered as a result of western disturbance only. However, the criterion for the identification of the westerly wave in monsoon season is defined in terms of rainfall and upper air charts as following. During winter season, there are some areas, where the rains occur due to the influence of western disturbance such as Kashmir, Balakot, Kakul, Gilgit, Skurdu, Bunji, Chalas, Astore, Hunza, Chitral and western parts of KPK. Further simultaneously if the rain occurs at the stations lie in middle or lower parts of country then it is also regarded as a result of the same. In addition, upper air charts of 500mb have been studied and where there is westerly trough found on the northern parts of the country along rain reported in above said areas then it is also deal of westerlies.

First of all total number of annual and monthly, events and days of western disturbance for the available period of 1973 to 2007 (35 years) are calculated and limned. After which the pervasive western disturbance is analyzed by dividing Pakistan into three regions/parts i.e. Northern (N), Northern and Central (N+C) and the whole Pakistan including the Southern region (N+C+S). Central (C) region of the country is considered in between the latitudes of 28^{o} and 31^{o}. Above 31^{o} and below 28^{o} latitudes, Northern (N) and Southern (S) regions are located respectively (Figure 1). Total number of annual and monthly events & days are calculated and depicted for the said regions. Seasonal number of events and days are assorted into four distinct seasons namely winter (January to March), pre-monsoon (April to June), monsoon (July to September) and post-monsoon (October to December), as classified by Faisal and Sadiq in 2009 [4].

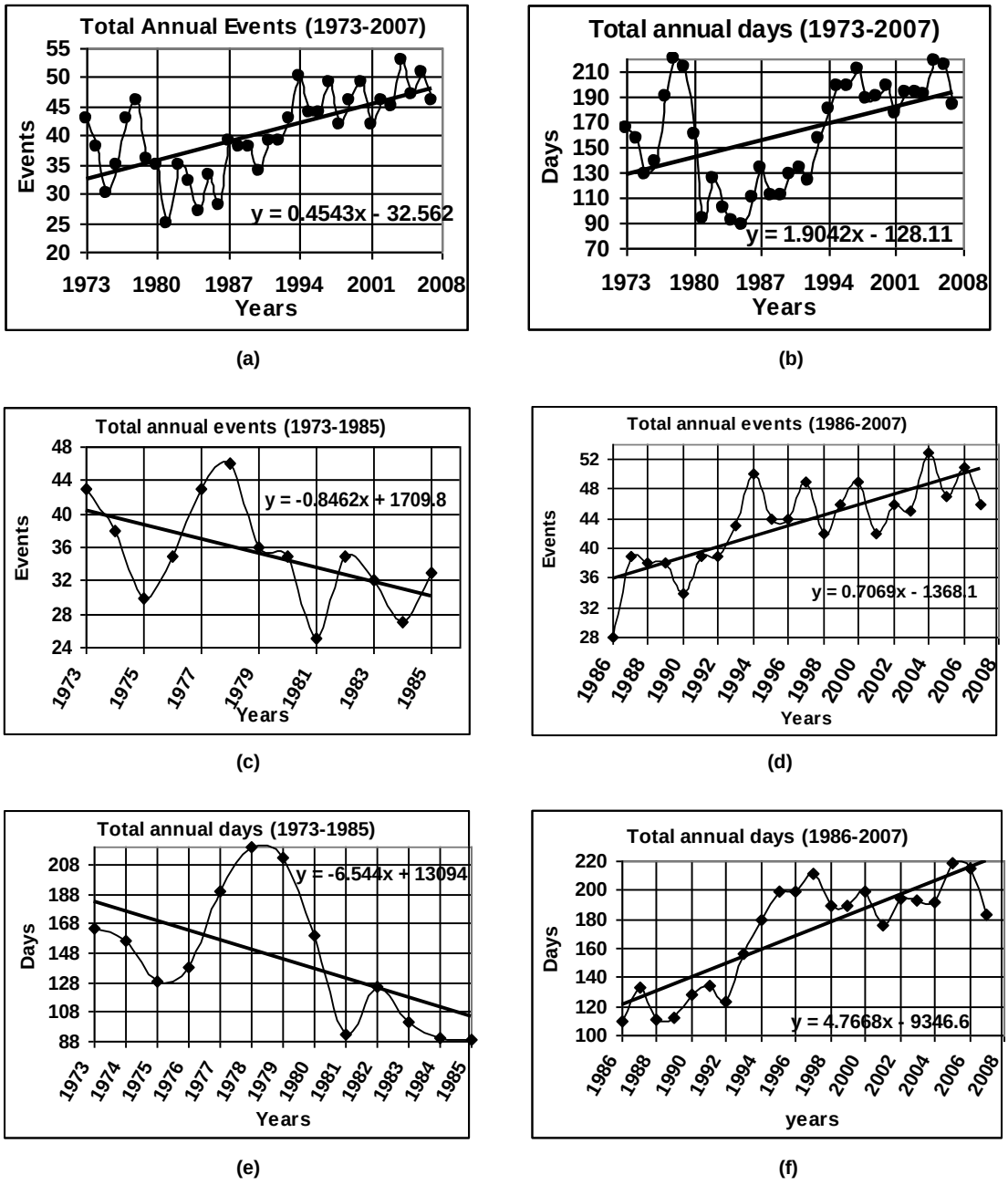

Fig 2(a-f). Total annual days and events for 1973-2007, 1973-1985 and 1986-2007.

Moreover, total monthly events and days for different regions and seasons are also calculated and depicted.

3. Findings and Discussion

3.1 Annual Analysis of Events and Days

After the year 1993, numbers of annual events are not found less than 41 e/y (Figure 2a). The minimum (25e/y) and maximum (54e/y) number of events observed in 1981 and 2004, respectively. It is evident from the same figure that increasing range of total annual events during the period 1973-2007 is 0.45 e/y. Trend from 1973 to 1985 indicates the decreasing tendency at the rate of 0.84 e/y while the period from 1986 to 2007 shows the increasing trend by 0.70 d/y (Figure 2c and 2d). The least period of the events appear from 1979-1991 but from 1991 and onwards, the events are continuously increasing.

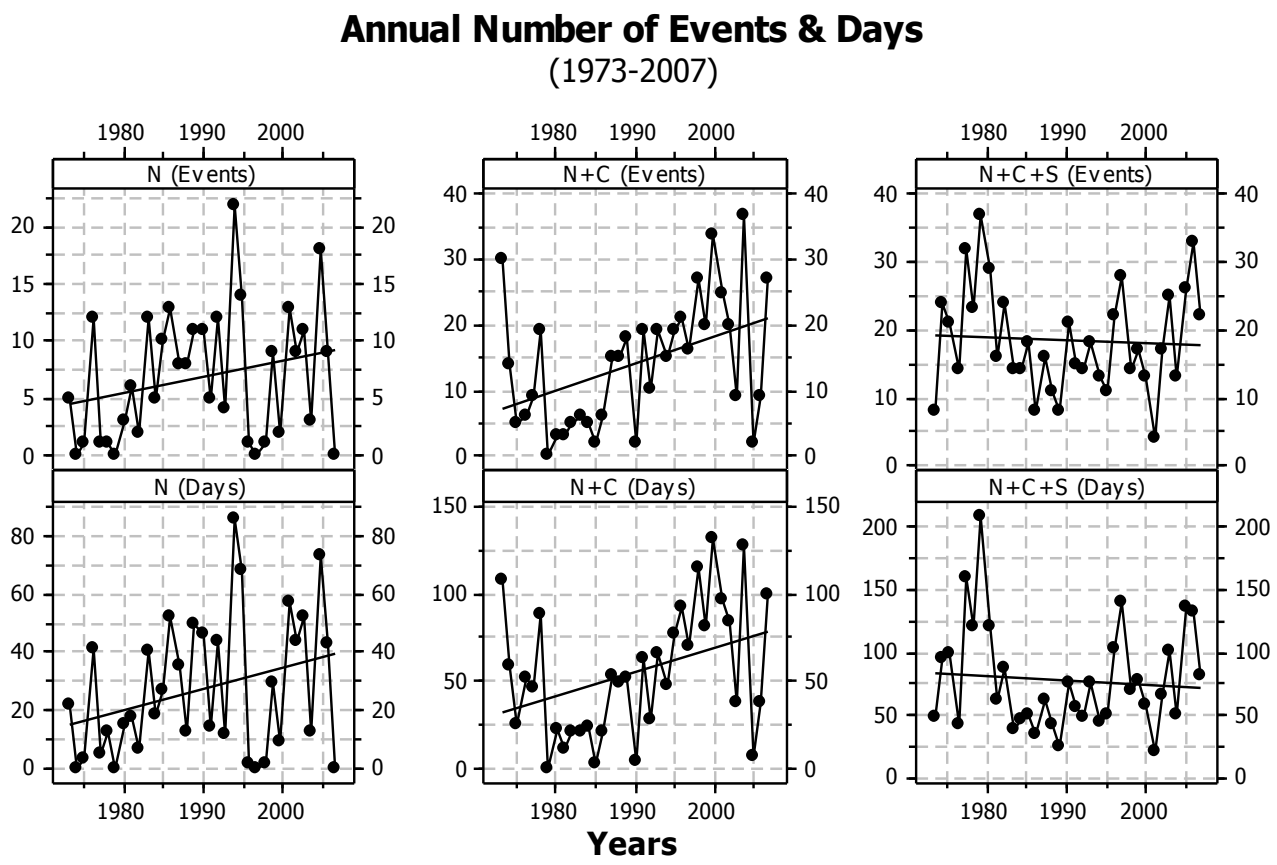

Figure 3. Total annual days and events of western disturbance for the described regions/parts of Pakistan.

The increasing tendency at the rate 1.90 d/y appears for annual days of the same period (Figure 2b). The lowest and highest numbers of days are recorded for 1986 (90 d/y) and 1978 & 2006 (212 d/y), respectively. Decreasing tendency from 1973 to 1985 indicates the decreasing rate of 6.54 d/y while the period from 1986 to 2007 shows the increasing trend by 4.76 d/y (Figure 2e-2f). The period from 1981-1992 (i.e. 11 years) comes out as the least period of western disturbance (regarding days) and the period from 1992-2007 (i.e. 15 years) comes out with continuously increasing rates.

3.1.1. Regional Analysis

Figure 3 indicates that both, annual events and number of days are increasing with time for the N and N+C region and decreasing for the region N+C+S. Rate of decrease for the events and days is -0.04 e/y and -0.31e/y, respectively. It is also found that events in N+C region are increasing at higher rate (0.41 e/y) than the N region (i.e. 0.14 e/y). In the similar fashion days for the N region are found at less increasing rate (0.70 d/y) than the N+C region (i.e. 1.37 d/y).

For region N, the maxima occur for both, days and events in 1994 while at the same time there were no westerly disturbance observed at the other parts of the country. The minimum frequency is noted for the years 1974, 1979 and 1997. For N+C the maximum and minimum values of N+C for events and days occurred in 1979 and 2004. For N+C+S the maximum and minimum values of disturbance are found for the years 1979 and 1971. Hence, if the number of events and days are maximum for one region they will be minimum for other regions and vice versa.

Annual number of days and total number of annual events are also analyzed through boxplots (Figure 4) as they are helpful to summarize the information in the data about the shape, dispersion, center and symmetry.

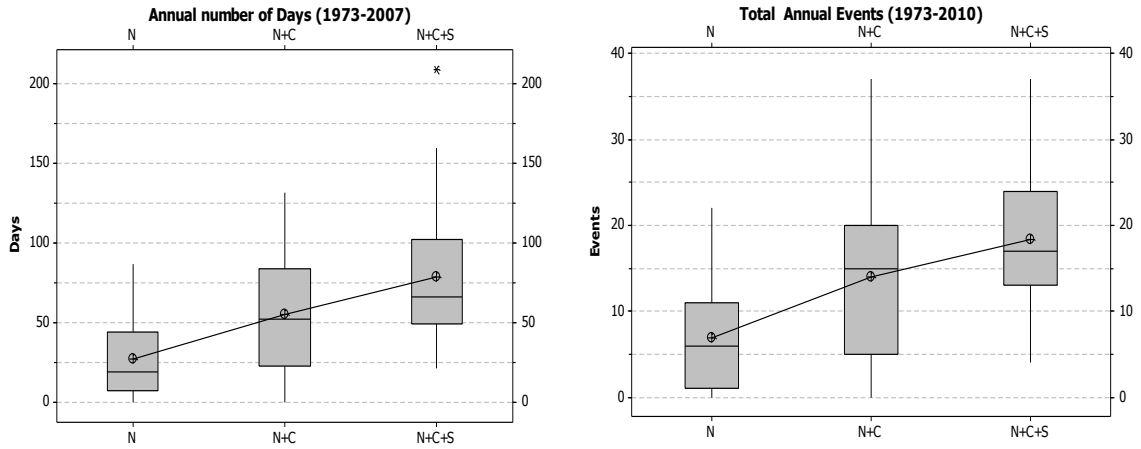

Figure 4. Total annual days and events of western disturbance for the described regions/parts of Pakistan.

Table 1. Total annual days and events with respect to regional classification.

	Region/Part	(Q1)	(Q3)	IQR= Q3-Q1	Median	Mean	Skewness
Annual Days	N	7	44	37	19	27.57	0.69
	N+C	23	84	61	52	55.54	0.39
	N+C+S	49	102	53	66	78.85	1.18
Annual Events	N	1	11	10	6	6.91	0.60
	N+C	5	20	15	15	14.05	0.53
	N+C+S	13	24	11	17	18.37	0.51

Table 2. Total annual monthly days and events with respect to regional classification.

	Region/Part	(Q1)	(Q3)	IQR= Q3-Q1	Median	Mean	Skewness
Annual Monthly Days	N	26.25	143	116.75	34.5	80.41	1.27
	N+C	77.25	244.25	167	160	162	0.29
	N+C+S	119	331	212	239.5	230	0.14
Annual Monthly Events	N	7	40	33	12	20.16	0.90
	N+C	22.5	59.75	37.25	40	41	0.20
	N+C+S	26.25	76.5	50.25	61.5	53.58	-0.17

As regards days, the region N+C+S (for annual days) and N (for monthly days) appeared with skewed distribution whose values are greater than one (Tables 1 and 2), hence median (the line drawn through the box) is not fall in the middle of the IQR box, and one whisker (the lines extending from the box) is noticeably longer than the other. The median is calculated by simply ranking the data and finding the middle observation (observation number [N + 1] / 2). If there are an even number of observations, the median is extrapolated as the value midway between that of observation numbers N / 2 and [N / 2] + 1) of the data. N+C region exhibits symmetrical data mode. A value of 209 days is considered as an outlier because it is outside of the box by more than 1.5 times the IQR. The values of first and third quartile, Inter quartile range along mean and median are summarized in Table 1.

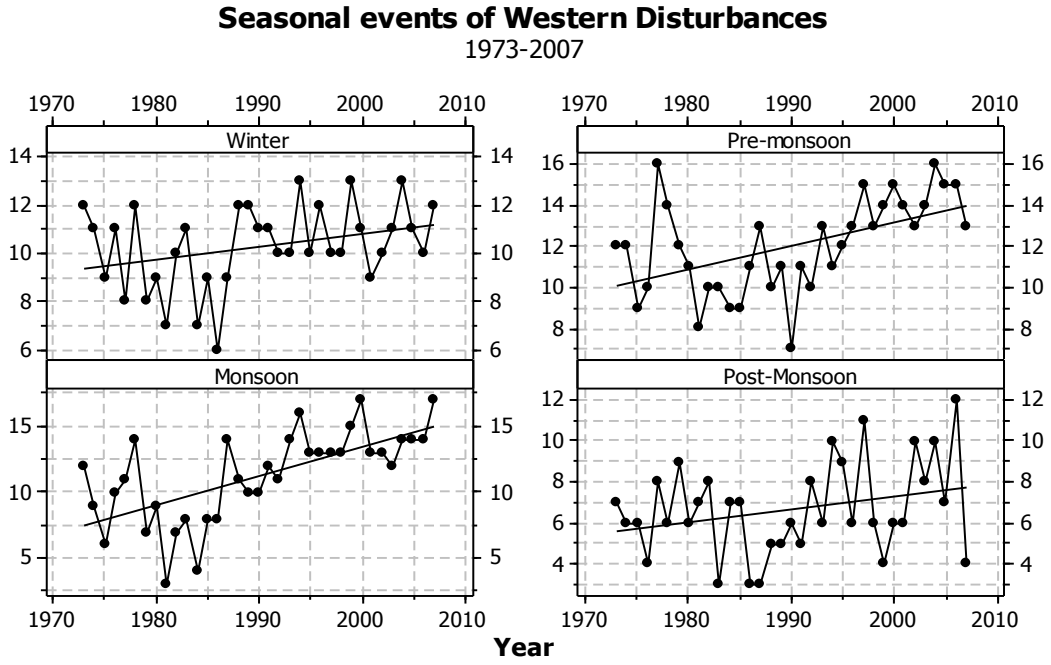

Figure 5a. Seasonal wise number of occurred events of western disturbance across Pakistan

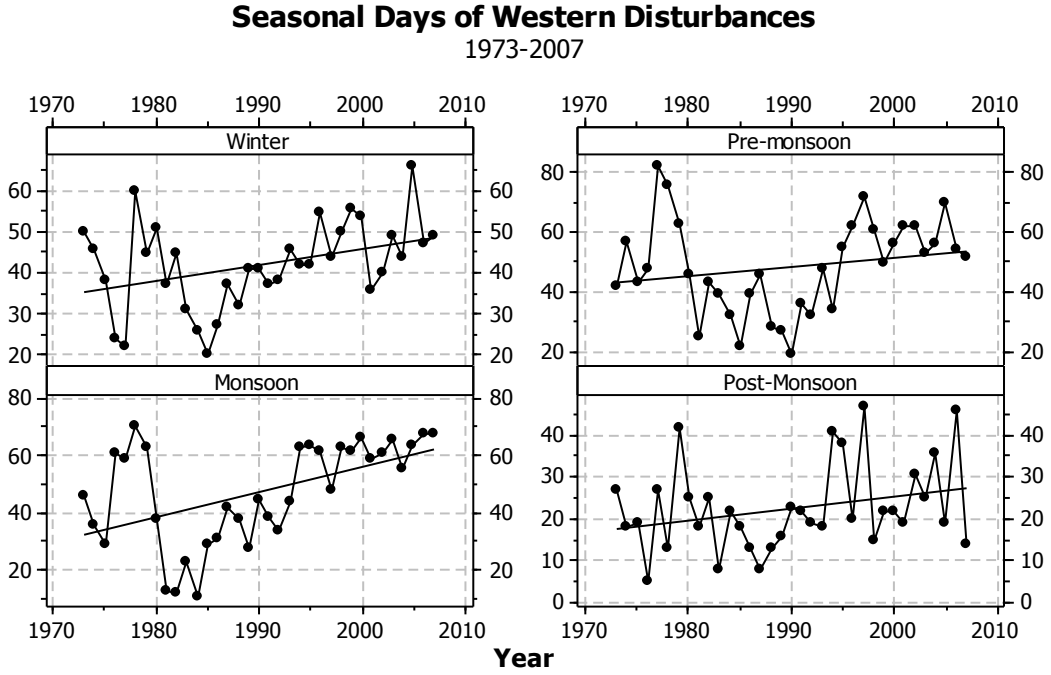

Figure 5b. Seasonal wise number of occurred days of western disturbance across Pakistan.

3.1.2. Seasonal Analysis

Events are increasing with time for every season (Figure 5a). The highest and lowest increments are found in monsoon (0.22 e/y) and winter (0.05 e/y) seasons. Post monsoon's value is near to winter (0.06 e/y) whereas pre-monsoon have relatively moderate value of 0.11 e/y. Seasonal days (Figure 5b) also contain highest increment of 0.89 d/y in monsoon but lowest value (0.29 d/y) is found for post-monsoon season. Pre-monsoon and winter seasons come out with 0.31 and 0.39 d/y.

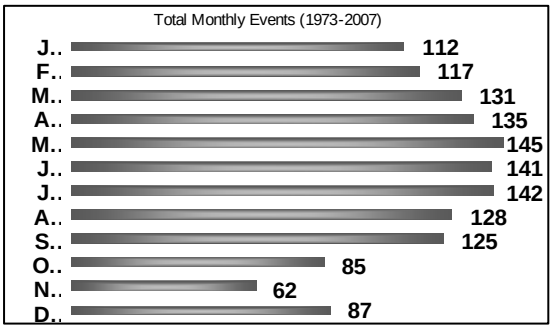

Figure 6a. Total monthly events of western disturbance.

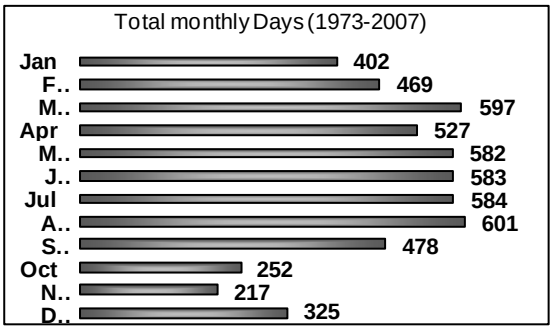

Figure 6b. Total monthly days of western disturbance.

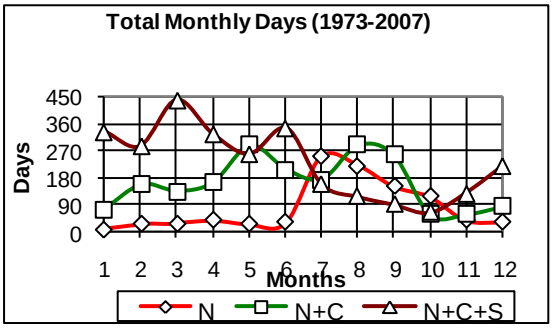

Figure 7a. Total monthly days of western disturbance for the described regions/parts of Pakistan

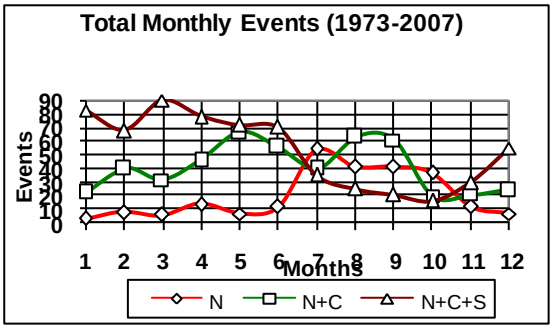

Figure 7b. Total monthly days of western disturbance for the described regions/parts of Pakistan

It has been explored that summer season comprised highest number of disturbances (for both events and days) than winter as there is no frontal characteristics is associated with the westerlies due to weak temperature gradient so it simply acts as a low pressure system which moves from west to east but not able to produce any kind weather.

3.2. Monthly Analysis of Events and Days

Events are most frequent during mid of the year i.e. May (145) June (141) and July (142) while least during the ending months of year i.e. for October (85), November (62) and December (87). The gradual increase and decrease from January to September and sharp decrease in October and November is noticeable (Figure 6a). Similarly highest days occur in the months of March, July and August while least for October, November and December (Figure 6b). Monthly days show almost same values in the months of May, June and July. August is the highest (601) while March has the second highest (597) values. Like the events, October and November also express abrupt decrease in days while the other months are not so gradually decreases as seen in event's case.

3.2.1. Regional Analysis

Monthly events and days show maximum departure in the end of winter (i.e. in March) while they are closest in the post monsoon months of October and November. The month of July is also important as days and events shift their relative positions in this month (Figures 7a & 7b).

Total monthly days for N+C and N+C+S have inverse relations. In January N+C is with increasing values while N+C+S is with decreasing values (Figure 7a). The same relation appears for almost whole year except in July when both are decreasing and meet at a single Point (~ 180 d/m). Simultaneously, very sharp increase is observed for N region. N+C and N+C+S again run across in October while N shows continuous and gradual decrease after July till December.

Total monthly events have the same pattern as of total monthly days (Figure 7b). The difference in N's region pattern after July appear with stable value from August to October and then sharp

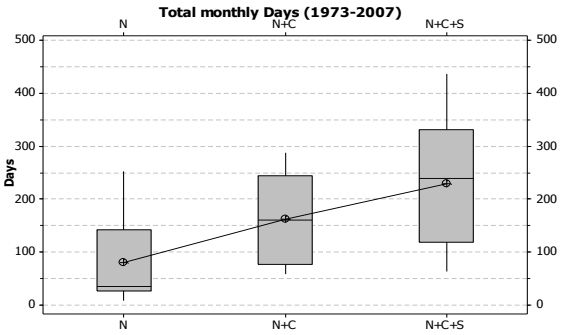

Figure 7c. Total monthly days of western disturbance for the described regions/parts of Pakistan

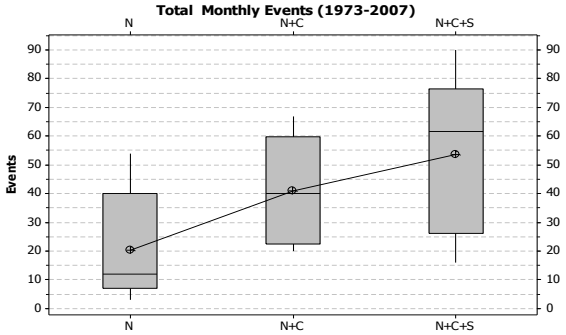

Figure 7d. Total monthly days of western disturbance for the described regions/parts of Pakistan.

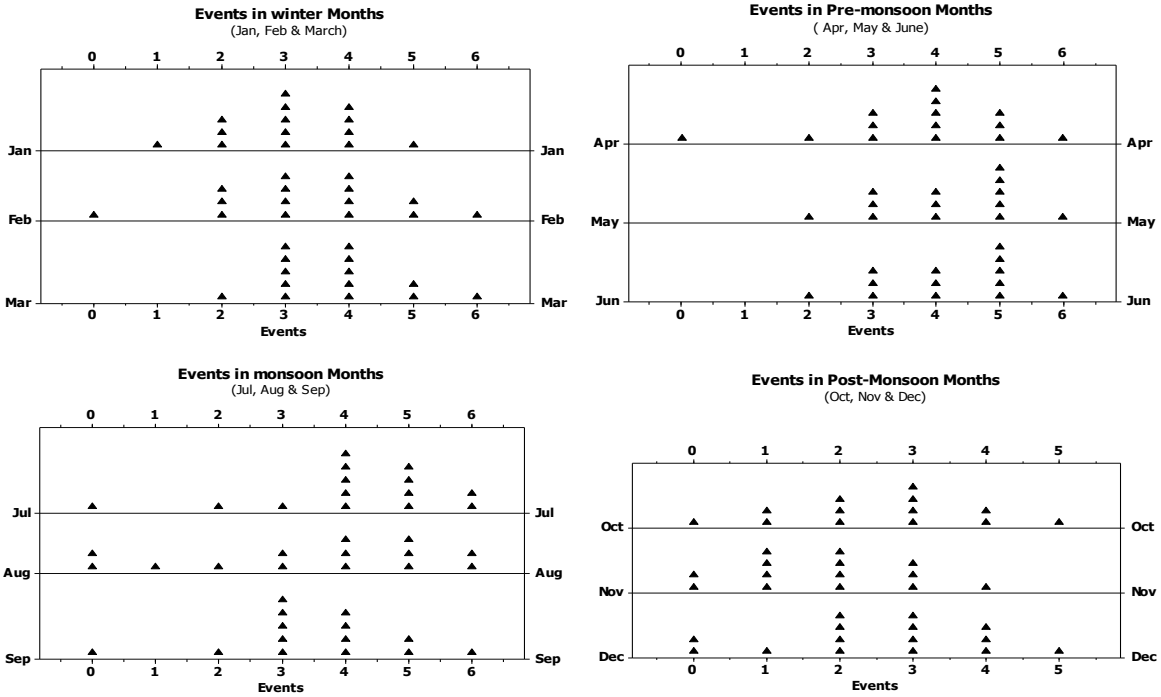

Figure 8(a-d). Seasonal (monthlies) events of western disturbance for 1973-2007.

decrease in November and then gradual decrease in December. N+C & N+C+S regions for total monthly days are more or less symmetric in nature. For the region N, third and fourth quartiles are dominating. The difference between mean and median is noticeable.

Total monthly days are also taken into account for box plot analysis (Figure 7c). It is found that N+C and N+C+S distribution is more or less symmetric while N region shows skewed distribution of the days with the value of 1.27. Figure 9d shows total monthly events for the same regions. The distribution of N appears with 0.90 skewness and N+C+S regions are found slight negatively skewed (–0.17) and this is the only negative value found in boxplot analysis. N+C is almost normally distributed. The values of first and third quartiles, Inter quartile range along mean and median are incorporated in Table 2.

3.2.2. Seasonal Analysis

Dot plots are the good demonstration to quantify and express the shifting patterns of parameter. In this study, these plots are used to observe the shifting pattern of events (Figures 8a & 8d) and days (Figures 9a & 9d). The most recurring events shifts to the range of 3 to 5 (in pre-monsoon, i.e.

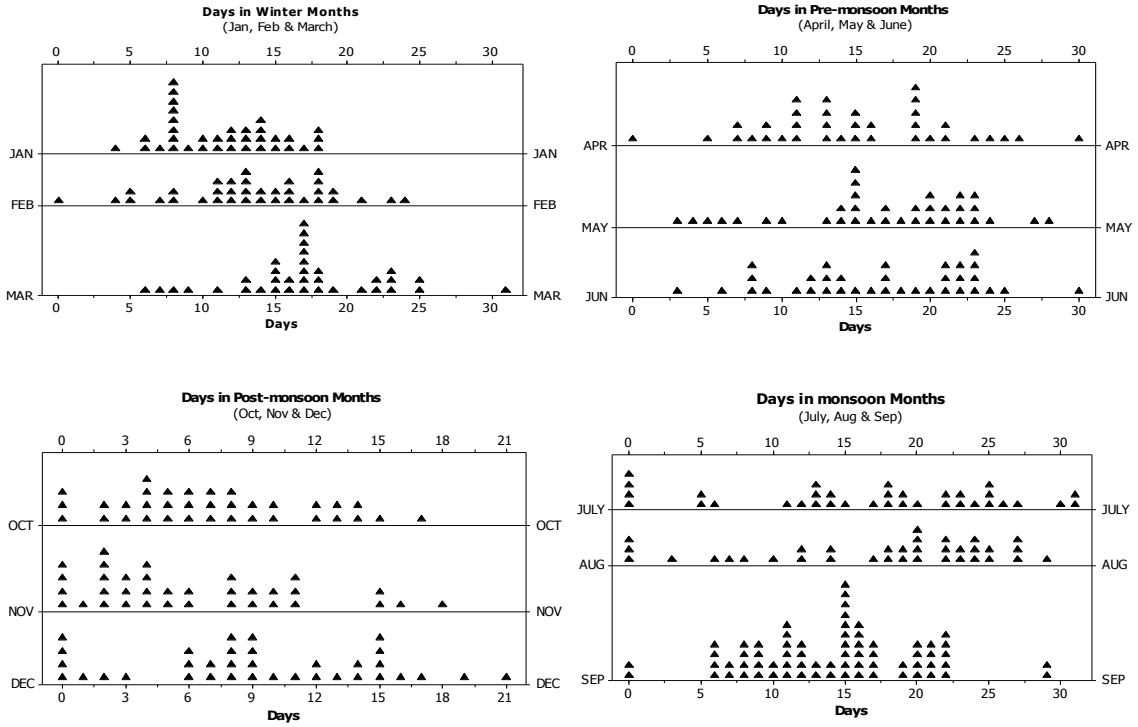

Figure 9(a-d). Seasonal (monthlies) days of western disturbance for 1973-2007.

March to June) from 2 to 4 in the December, January & February. July and August have maximum events from 4 to 5 and then recession starts from September to November with maximum frequency ranging from 1 to 2 events. As regard the days (Figure 9a & 9d), months from October to December appears with least number of days. Mostly are scattered and lying in the general range from 0 to 15. March to August appear with the most range of days, September has shrank for 6 to 20 days, while January and February reduced for 6 to 18 days.

4. Summary, Conclusion and Future Outlook

4.1. Annual Events and Days

- Total annual events and days during the events are found increasing at the rate of 0.45 e/y and 1.90 d/y. After breaking the period, decreasing and increasing trends come out for the period 1973-1985 and 1986-2007.
- Region wise study shows that annual events and days are increasing for N and N+C region while decreasing trend is seen for N+C+S region.
- All the seasons appear with increasing trends of annual days and events. The highest increment per year is found for Monsoon for both; days and events.
- The symmetry and distribution explored that total monthly events for all the regions are almost normally distributed.

4.1.2. Monthly Events and Days

- Total monthly events are highest in May, June and July while least in October, November and December. Total monthly days express almost same higher values for May, June and July but the highest values are observed for August and March. Least values are in the months of October, November and December.
- Regional wise study appears with a particular pattern regarding days and events. N+C and N+C+S regions indicate inverse relationship regarding western disturbances while N region shows a particular relation to the combined effect of above said regions. This study for total monthly days establishes the normal distribution pattern for N+C and N+C+S.
- Most recurring events days occurred in premonsoon and monsoon seasons.

Acknowledgements

The authors are thankful to Mr. Akhlaq Jameel (Meteorological Forecaster), for offering his valuable help in investigation of synoptic features of some events.

References

[1] P. K. Das, The Monsoon, National Book Trust, India (1996).

[2] M. Muslehuddin, H. Mir and N. Faisal, Pak. J. Meteorol. **2**, No. 4 (2005) 91.

[3] Sarfaraz, Pak. J. Meteorol. **4**, No. 7 (2007) 55.

[4] N. Faisal and N Sadiq, Pak. J. Meteorol. **6**, No. 11 (2009) 51.

[5] N. Sadiq, Astroph. Appl. Math. **1** (2009) 147.

[6] N. Faisal and N. Sadiq, The Nucleus **49**, No. 3 (2012) 239.

[7] N. Sadiq, The Nucleus **49**, No. 3 (2012) 231.

[8] K. M. Shamshad, The Meteorology of Pakistan, Royal Book Company, Karachi (1988).

[9] J. A. Khan, The Climate of Pakistan, Rehbar Publishers, Karachi (1993).

[10] S. Gibilisco, Meteorology Demystified, A Self Teaching Guide, McGraw-Hill, USA (2006).

[11] G. B. Pant and K. R. Kumar, Climate of South Asia, John Wiley and Sons, England (1997).

[12] F.K. Lutgens and E. J. Tarbuck, The Atmosphere: An Introduction to Meteorology, 11th Edition, Prentice Hall, US (2010).

[13] F. M. Q. Malik, Western Disturbances 'A State-of-the-Art Report', SAARC, Pakistan (1990).