Feature Article

A Climatological study between solar activity and Extreme events around the globe

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Abstract:

Variations of sunspot numbers in connection with extreme events like flood, storm, drought, seismic activity, volcanic activity, extreme temperature and sum of all events, defined as total event is studied. We have used Fourier analysis to investigate whether any periodic relation exists between Sun and extreme events. Correlation analysis is also employed to find if there is any relation between solar activity and extreme events exists. Finally, we present the comparison of extreme events with solar activity around sunspot maximum. Our study reveals that the maximum occurrence of drought is observed in the growth phase of solar activity whereas the maximum occurrence of other events coincide either with the sunspot maximum or in the declining stage of solar activity. Besides this we find that the seismic activity relates well with solar activity and the occurrence of maximum number of earthquakes shifted slightly from the time of Sunspot maximum.

Keywords: Earthquake, Extreme events, Sunspot, Earth

Introduction:

The Earth is a dynamic system, constantly changing as matter and energy are transferred among its different parts-the geosphere, the hydrosphere, the atmosphere and the biosphere. Natural hazards strongly influence the biosphere. The Sun is the most important driving force for our earth. Recent scientific reports suggest that the solar activity changes the earth's climate and also triggers extreme events. Civilization's For the interest of civilization, predicting the location and time of damaging events like seismic activity, drought, flood and other extreme events is necessary. The potential for devastation of property that otherwise could be secured and the loss of life that otherwise could be prevented are powerful reasons to find predictive factors. The Sun's output varies on a wide range of time scales from minutes in the case of some transient events to the billion year time scale of solar evolution. Short term variations include the transient episodes of solar activity like flares or coronal mass ejection those due to the 27-day apparent rotation period of the Sun and 154-158 day cycle which exists in many solar phenomenon. Intermediate term variations include the 16-month cycle discussed quite recently by Solar Heliospheric observatory (SOHO) (http://sohowww.nascom.nasa.gov/). Long term variations include 11-year solar cycle which is by far the better established cycle of solar activity together with the 22-year Hale cycle of magnetic activity, the 80 to 90 year Gleissberg cycle etc. The question of whether variations in solar activity exert any effect on climate has been under investigations since long. Odintsov et al (2006) compared the century scale and decadal variations of seismic activity and tried to relate century-scale and decadal changes of solar geomagnetic activity. Also in 2007, Odintsov et al have studied the character and possible

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successions of cause-effect relations between Sun and Earth from several days to the 11-year solar cycle. It has also been indicated that the maximum of seismic energy released from earthquakes in 11-year cycle of sunspots is observed during the declining phase of solar cycle and lags 2-year behind the solar cycle maximum. It has also been established that the maximum number of earthquakes directly correlates with the sudden increase in the solar wind velocity. De et al (2005) presented a factual and brief review of the extreme weather events that occurred in India during the last 100 years. Their work suggests that the socio-economic impacts of the extreme events such as floods, droughts, cyclone, thunderstorm, heat and cold waves have been increasing due to large growth of population and its migration towards urban areas. Thus, greater efforts are needed to improve the forecast skill so as to better the forecasts in disaster management. Zhongrui et al (2003) investigated the relationship between the length of the solar cycle, a good indicator of long term change in solar activity, with natural disasters (floods, droughts, earthquakes) in China during the last 108 years. The results suggest that the length of solar cycle (LSC) may be useful indicator for drought/flood and intense earthquakes. They also obtained that the solar activity strengthens with the shortening of LSC and more floods occur in South China and frequent earthquakes happen in Tibetan Plateau. Solar activity may play an important role in the climate extremes and behavior in the lithosphere. Yangquan (1993) has shown that maximum floods were often observed in the periods when the number of sunspot numbers were decreasing from the maximum stage or decreasing to the minimum stage. Dmitrieva et al (1998) found maximum occurrences of droughts, epidemics and epizootics either coincide with the sunspot maximum or are observed in the growth phase of solar activity whereas for every cold winters the correlations with solar activity was not so pronounced.

In this research paper, we have presented some results of different effects due to the variation of solar activity with extreme events. Fourier analysis is used to calculate the periodicity between the solar parameters and extreme events. Next, using correlation analysis we tried to establish whether there is any linear relationship between solar activity and these extreme events or not. Finally, different events of natural hazards are compared around the sunspot maximum to conclude whether these events are controlled by growth or declining stage of solar activity or not.

Data:

Emergency events Database (EM-DAT) is a global database on natural and technological disasters that contains essential core data on the occurrence and effects of more than 17,000 disasters in the world from 1900 to present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the school of public health of the universite catholique de Leuven located in Brussels, Belgium. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. Priority is given to data from UN agencies, governments and the International Federation of Red Cross and Red Crescent societies. This prioritization is not only a reflection of the quality or value of the data, it also reflects the fact that most reporting sources do not cover all disasters or have political limitations that could affect the figures. The entries are constantly reviewed for redundancy, inconsistencies and incompleteness. CRED consolidates and updates data on a daily basis. A further check is made at monthly intervals. Revisions are made annually at the end of each calendar year. For a disaster to enter into the database at least one of the following criteria must be fulfilled: ten or more people reported killed, hundred people reported affected, declaration of a state of emergency, call for international assistance. In our present study we mainly consider extreme events as flood, drought, storm, volcanic activity, seismic activity, extreme temperatures and collective effect of all events as total events. We use the data from EMDAT, www.emdat.net: Universite catholique de Leuven Brussels, Belgium. The time span considered in our investigation is from 1900-2006. As a measure of solar activity we use the sunspot numbers provided by National Geophysical Data Center (NGDC) http://www.ngdc.noaa.gov.

Observations and Results:

The Fourier analysis is used to investigate common periodicities between two series of data. By

Fourier transform, it is possible to build a graph showing power density versus frequency (scale) and how they vary with time. The time scale or periodicity is obtained by taking the inverse of frequency (scale) at several maximum power or amplitude (peaks). In the present work, we tried to evaluate periodicity of each extreme event from 1900 to 2006 and compare the periodicity between sunspot numbers and extreme events. This is done to find if there is any periodic relation between solar activity and extreme events. Sunspot numbers shows periodicity at 11, 22 using Fast Fourier transform and matches well with Eicher (2008) and Zhao et al (2007).

Table 1: The result of Fast Fourier Transform (FFT) of different extreme events at different location. The periodicity is expressed in years (yr).

Regions	Drought	Earthquake	Flood	Storm	Extreme Temperature	Volcano	Total Events
Africa	20.7 13.4 4.1 3.4	21.8 14.1 3.4 2.7	10.6 6.9 4.6 4.0	15.6 5.4 3.3 3.1	6.3 4.8 2.8 2.3	15.3 6.3 3.0 2.8	22.8 14.3 10.4 6.5
America	20.2 6.4 3.8 3.0	11.4 3.7 3.4 2.3	21.2 13.9 7.8 6.5	18.2 8.4 5.1 13.7	17.5 3.2 2.7 2.5	9.1 4.9 4.2 3.3	13.8 9.0 6.5 2.8
Asia	19.3 12.0 7.3 5.9	12.3 4.7 3.9 3.1	13.1 10.0 7.0 5.1	13.1 7.2 6.2 3.9	5.5 2.5 2.7 2.2	13.7 3.6 3.3 3.8	13.2 9.9 7.2 6.1
Europe	12.1 9.6 3.8 3.5	19.6 13.3 6.9 4.2	13.2 7.8 6.3 5.1	18.3 8.4 3.1 2.7	7.3 6.0 2.8 2.7	6.3 4.3 2.6 2.7	13.7 8.4 6.1 2.7
India	10.9 6.8 5.4 4.4	11.4 3.8 3.4 2.2	19.2 14.0 10.6 7.8	35.2 4.6 4.2 3.3	34.9 10.0 8.2 3.1	35.4 10.7 7.8 5.8	35.4 10.7 7.8 5.8
World	18.4 12.0 3.6 2.8	18.4 12.1 4.6 4.2	9.7 6.8 5.9 4.8	18.4 13.3 7.6 2.9	6.7 5.4 3.2 2.5	18.4 13.4 7.7 2.9	12.9 7.6 5.9 2.5

Table 1 summarizes the periods of extreme events such as drought, storm, flood, extreme temperatures, seismic activity, volcano and total events in Africa, Asia, America, Europe, India and World. Here we investigated the periodicity in different regions to find whether solar activity is related to extreme events in all places of the world. Figure 1(a)-1(f) represents First Fourier Transform of drought in places mentioned above. In almost all places, the 2-5 and 9-11 year periodicity is common. Africa, America and Asia contains periods around 22-years. Figure 2(a)-2(f) shows Fourier transform of seismic activity in all mentioned places. In the present analysis on seismic activity, a significant short period around 2-5 year is found in all places. The periodicity around 11 year is found in almost all the places. America, Europe, India and World contain 22-year periodicity on seismic activity. Figure 3(a)-3(f) resembles Fourier analysis of flood around different regions. Africa, Asia, Europe, India and world shares common periodicities of 2-5 years and around 11 years. America shows 22 years periodicity in addition to 13.9, 7.8 and 6.5 year periods. Fourier analysis of storm is presented in Figure 4(a)-4(f). 2-5 years periodicity is common to all regions. 15-19 year periodicity is common in Africa, America, Europe, India and World. First Fourier transform of extreme temperature as shown in Figure 5(a)-5(f) evaluates significant common periodicities from 2-6 years. Similar analysis is used to study volcano in different regions (Figure 6(a)-6(f)). Here short period around 2-5 year is well supported by almost regions. Total events are the sum of all the events occurring in any particular region and the Fourier analysis is presented in Figure 7(a)-7(f). The extreme events show shorter periods around 2-5 years. In addition to these shorter periods the mentioned natural hazards also shows 11 and 22 years periodicity like the periodicity of solar activity. Therefore one may say that the period of occurrence of these events is controlled by Sun. A connection between solar activity and the extreme events is studied further using correlation study we try to determine whether a linear relationship between two variables exists or not and also it provides a measure of the strength of this relationship. It is important to remember that the correlation coefficient between two variables is a measure of their linear relationship, and a value of correlation coefficient equal to zero implies lack of linearity and not a lack of association. In this investigation, the most widely used linear correlation between two variables is called the Pearson correlation coefficient (p-value) is used. The p-value is the probability that one would find the current result if the correlation coefficient were in fact zero (null hypothesis). The significance of correlation is nothing but given by p-value with 95 % significance if p-value is less than 0.05. We have considered sunspot numbers as a proxy to solar activity. Therefore calculating correlation coefficient (r) between sunspot numbers and all the components of extreme events, one may hint a relation between them. The calculated correlation coefficient between Sunspot numbers and different events are low valued and are not statistically significant. The sign of the correlation coefficient suggests that solar activity may control extreme events in positive direction. The low r values may be explained as solar activity is not only the factor affecting these hazards. The statistical significance which is not 95% significant as given by p-value may be due to insufficient data.

In this section we have superposed Sunspot numbers and extreme events data around the years of Sunspot maximum for the period 1900-2006. The periods of solar activity with maximum and minimum years are depicted in Table- 3. In the figure 8-13, the x-axis represents superposed years where '4' on x-axis shows years of Sunspot at its peak The number '1 to 3' on the x-axis represents years at early stage of Sunspot maximum. The numbers '5 to 7' shows years after Sunspot maximum. Thus we label x-axis of Figure 8-13 as "years relative to Sunspot maximum" or "years around Sunspot maximum". The sunspot numbers data are taken from National Geophysical Data Center (NGDC) http://www.ngdc.noaa.gov. The extreme events data are taken from EMDAT, www.emdat.net. After comparing the extreme events with sunspot numbers around sunspot maximum years, we find that our results come out to be very interesting (Table 4). We find that in the year of sunspot maximum, drought events shows minimum occurrence. Also, the peak of drought occurs during the early stage of solar activity (Figure 8). We also observed another interesting result. We find minimum flood events during sunspot maximum while maximum flood occur during the decreasing phase of the solar activity (Figure 9). When we compare solar activity with storm we observe the peak of storm events in the declining stage of solar activity (Figure 10). The storm minimizes at maximum sunspot. Similarly, volcano events minimizes at maximum solar activity. Volcano has its peak during the decreasing phase of sunspot activity (Figure11). The total events occur in the descending

Table 2: The correlation coefficient (r) between sunspot and different extreme events, with p-value in brackets.

	Flood	Storm	Volcanic activity	Seismic activity	Extreme temperature	Drought	Total events
Sunspot Numbers	0.09 (0.34)	0.19 (0.06)	0.05 (0.64)	0.24 (0.01)	0.09 (0.36)	0.22 (0.02)	0.15 (0.12)

Table 3: The presentation of Sunspot numbers with the respective years of maximum and minimum.

Sunspot Cycle Number	Year of minimum	Yearly smallest Sunspot number	Year of maximum	Yearly largest Sunspot numbers
14	1901	2.7	1905	63.5
15	1913	1.4	1917	103.9
16	1923	5.8	1928	77.8
17	1933	5.7	1937	114.4
18	1944	9.6	1947	151.6
19	1954	4.4	1957	190.2
20	1964	10.2	1968	105.9
21	1976	12.6	1979	155.4
22	1986	13.4	1989	157.6
23	1996	8.6	2000	119.6

Table 4: The results showing the comparison between Sunspot numbers and extreme events data around the years of Sunspot maximum for the period 1900-2006.

Events	Occurrence of these events around years of Sunspot maximum
Drought	Minimum drought events coincide with Sunspot maximum (year 4 as shown in x-axis of Figure 8). Two maximum events occur at year 2 i.e at early stage of solar activity and at years at 5-7 which is the descending stage of solar activity.
Flood	Minimum coincides with Sunspot maximum and maximum coincides with year 6 i.e at the descending phase of solar activity.
Storms	Minimum occurrence takes place at year 4 which sunspot maximum year and maximum occurrence is observed at year 5.
Volcanic activity	Minimum occurrence takes place at year 4 and maximum events occurs at year 6.
Total events	Maximum events take place at year 5 and minimum at year 4.
Seismic activity	Minimum occurrence takes place at year 3 and maximum at year 5.

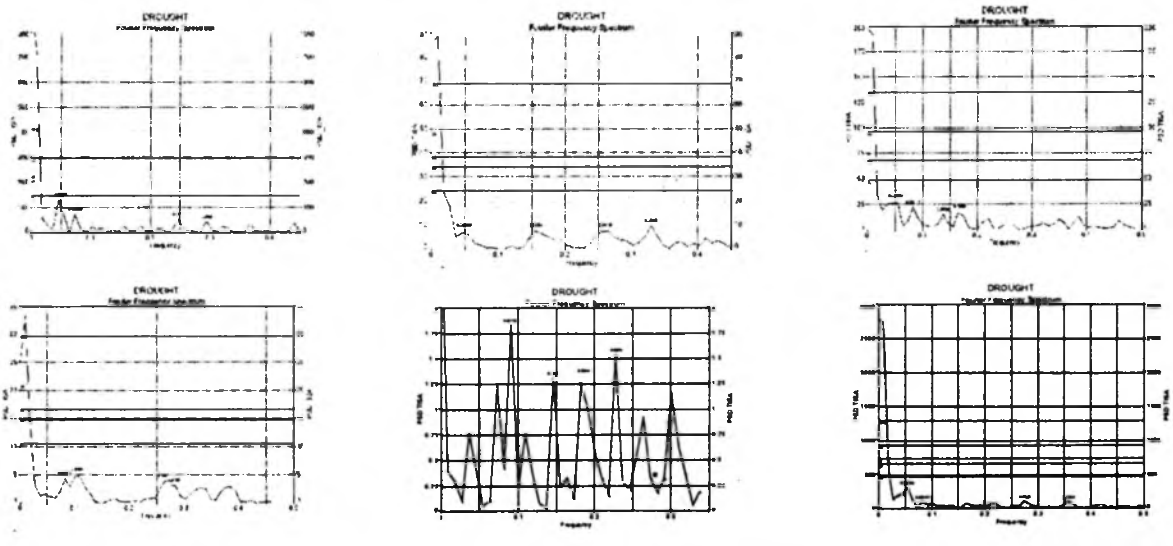

Figure 1(a)-1(f) represents Fast Fourier Transform (FFT) of drought at different places mentioned in Table-1. The power is plotted in x-axis and frequency in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

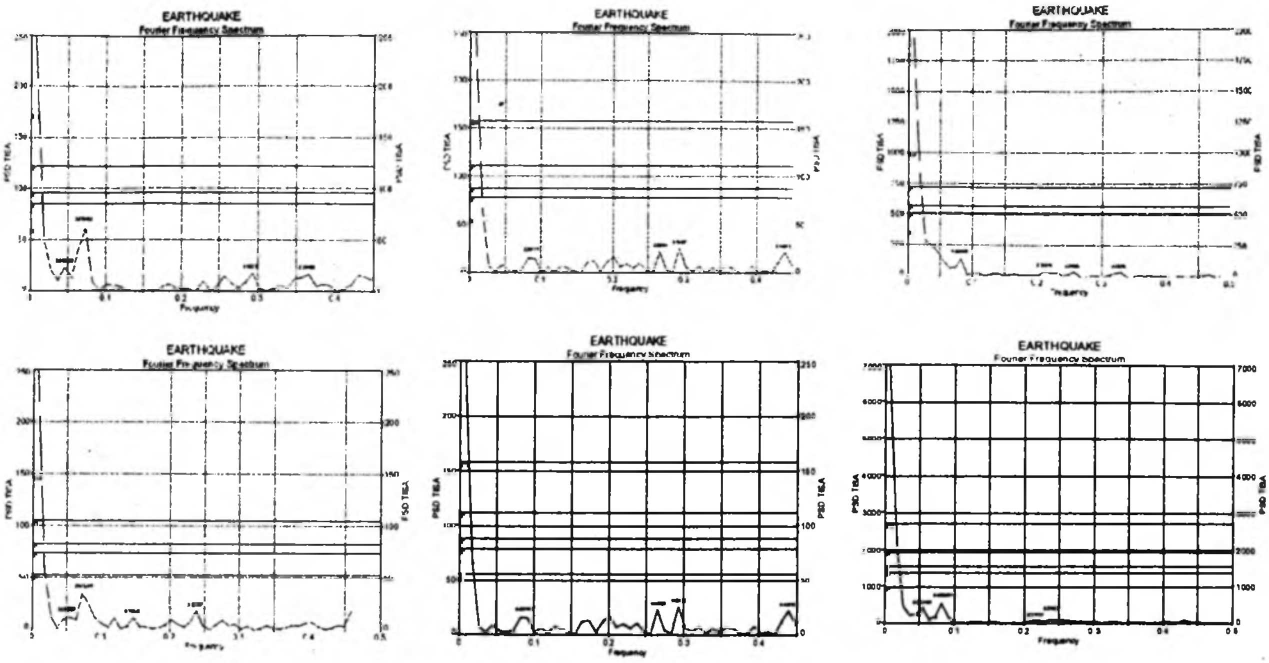

Figure 2(a)-2(f) represents Fast Fourier Transform (FFT) of seismic activity at different places mentioned in Table-1. The power is plotted in x-axis and frequency in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

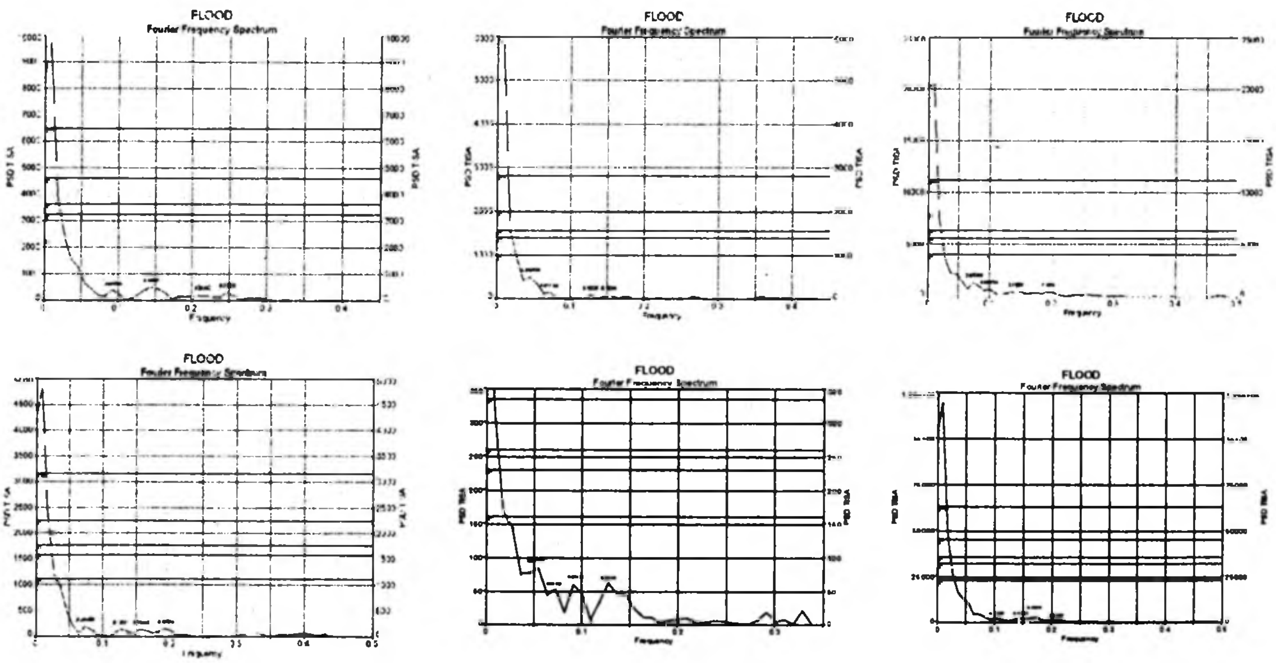

Figure 3(a)-3(f) represents Fast Fourier Transform (FFT) of flood at different places mentioned in Table-1. The power is plotted in x-axis and frequency in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

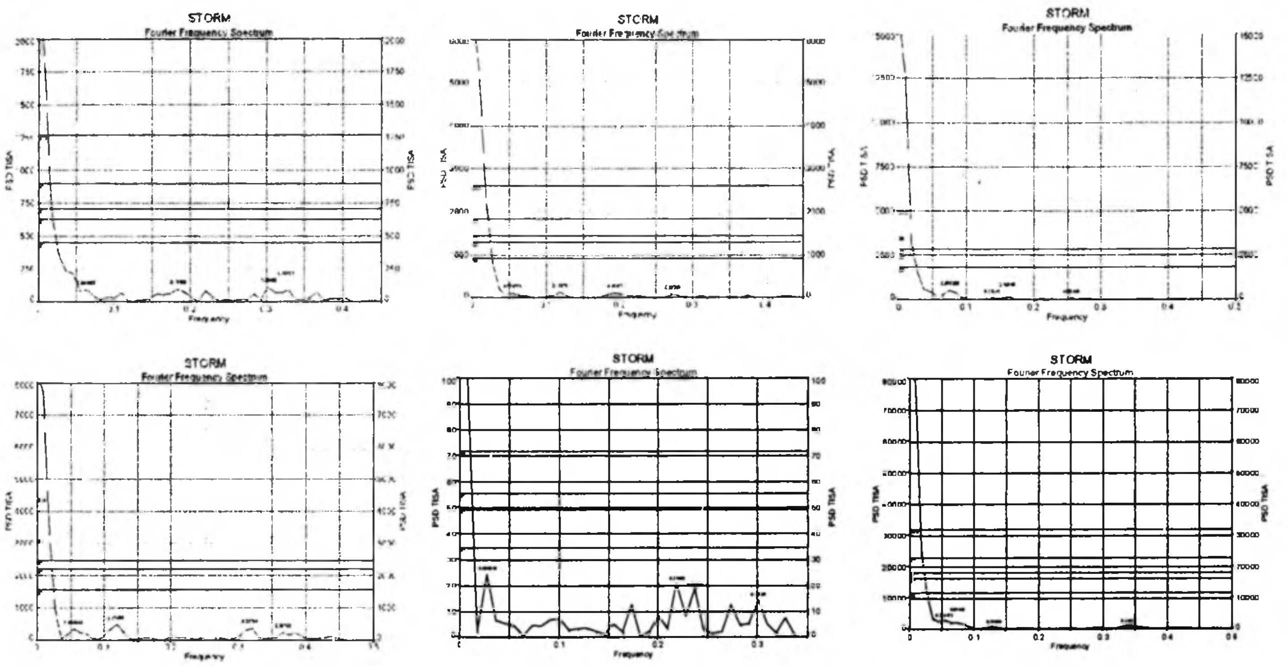

Figure 4(a)-4(f) represents Fast Fourier Transform (FFT) of storm at different places mentioned in Table-1. The power is plotted in x-axis and frequency in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

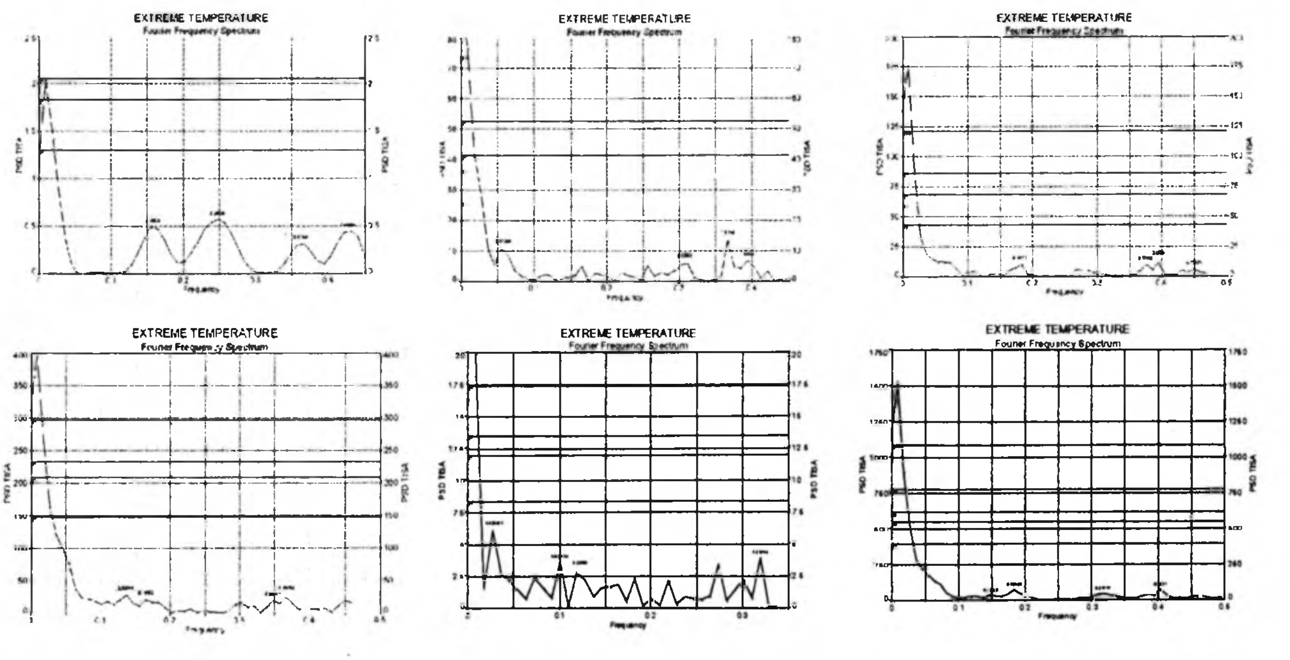

Figure 5(a)-5(f) represents Fast Fourier Transform (FFT) of extreme temperature at different places mentioned in Table-1. The power is plotted in x-axis and frequency in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

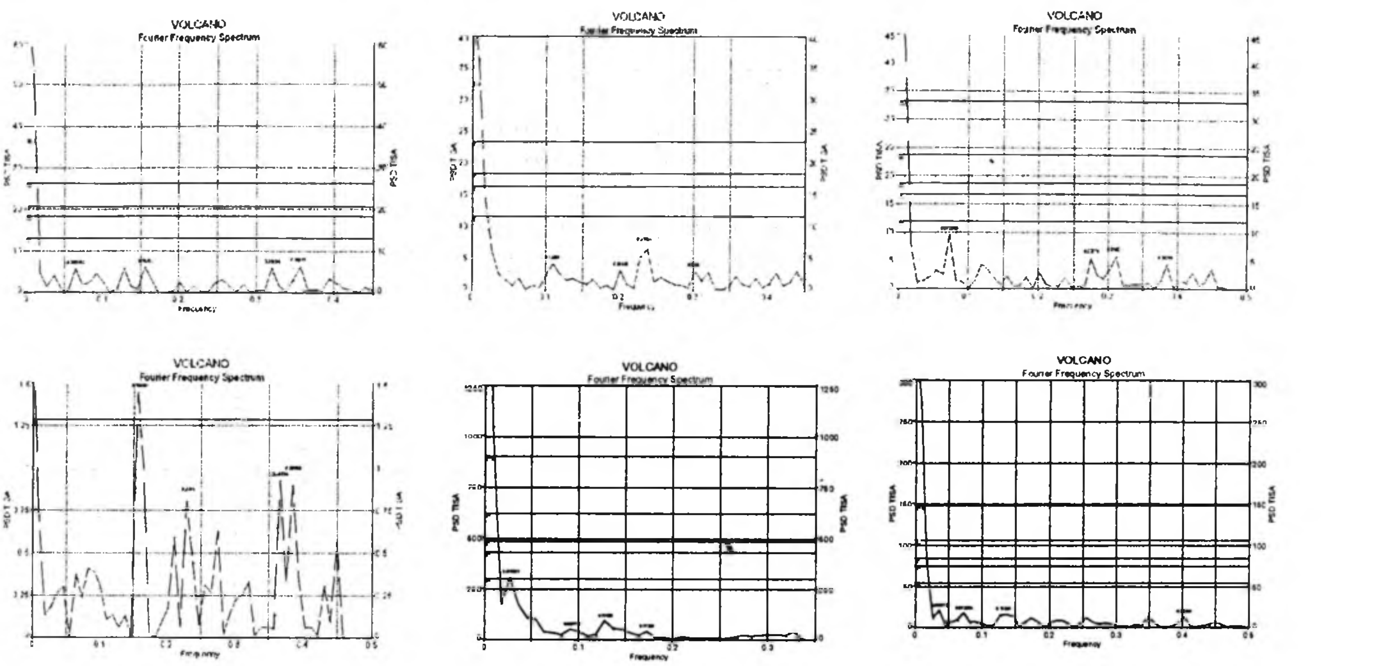

Figure 6(a)-6(f) represents Fast Fourier Transform (FFT) of volcanic activity at different places mentioned in Table-1. The power is plotted in x-axis and frequency in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

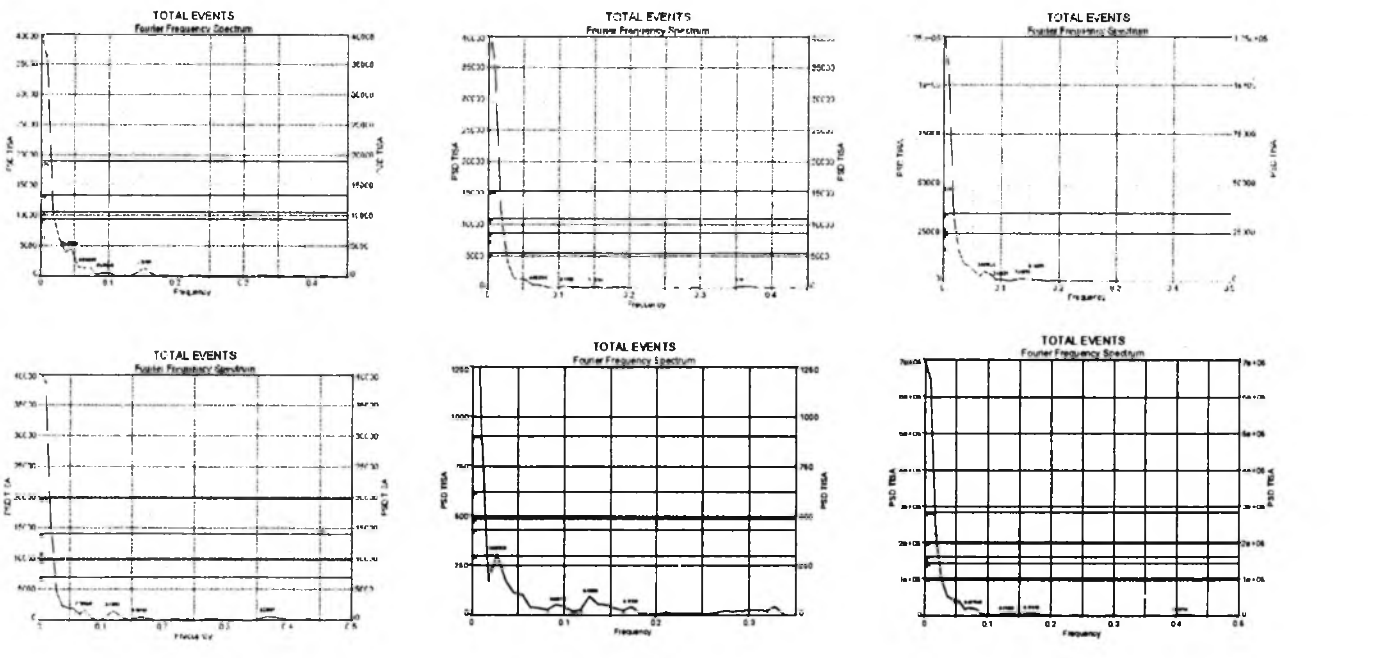

Figure 7(a)-7(f) represents Fast Fourier Transform (FFT) of total events at different places mentioned in Table-1. The power is plotted in x-axis and in y-axis. The peaks determine the periodicity of the time series in years. The captions (a) to (f) represent Africa, America, Asia, Europe, India and world

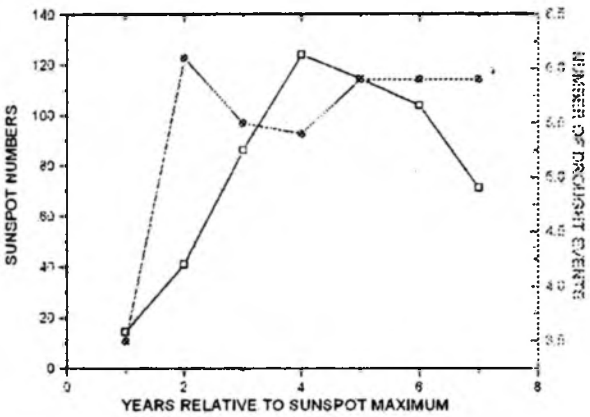

Figure 8 shows comparison between sunspot numbers and drought events around sunspot maximum years. Symbol ? represents sunspot numbers and represents drought events.

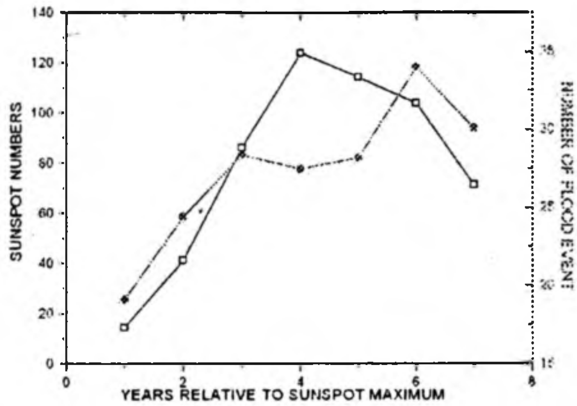

Figure 9 shows comparison between sunspot numbers and flood around sunspot maximum years. Symbol? represents sunspot numbers and represents flood.

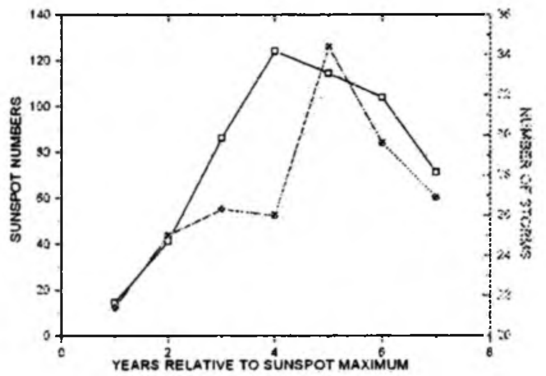

Figure 10 shows comparison between sunspot numbers and storms around sunspot maximum years. Symbol ? represents sunspot numbers and represents storm

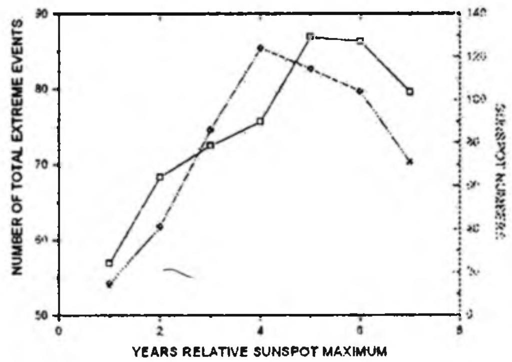

Figure 12 shows comparison between sunspot numbers and total events around sunspot maximum years. Symbol represents sunspot numbers and? represents total events.

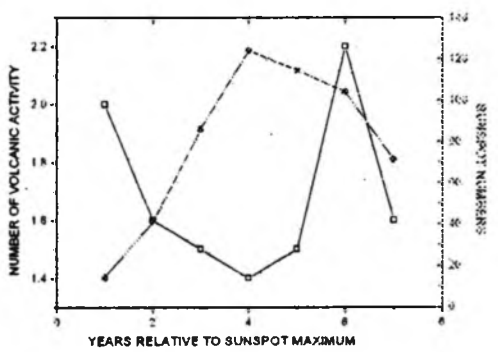

Figure 11 shows comparison between sunspot numbers and volcanic activity around sunspot maximum years. Symbol represents sunspot numbers and ? represents volcanic activity.

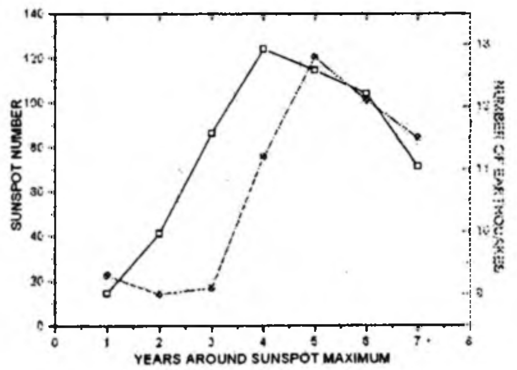

Figure 13 shows comparison between sunspot numbers and seismic activity around sunspot maximum years. Symbol • represents sunspot numbers and ? represents seismic activity.

phase of sunspot cycle of sunspot maximum (Figure 12) and the maximum seismic activity is found close to sunspot maximum (Figure 13). The above analysis helps us to say that the occurrence of these events at its peak takes place after years of solar activity at its maximum. This may be explained in a way that solar signal take some time to influence or trigger the natural hazards from its peak stage.

Conclusion:

The present work continued the consideration of the possible correlation between characteristics of solar activity and extreme events in time period from 1900-2006. The main results of this work are as follows:

1. Periodicity as determined by Fourier analysis shows that most events are comparable with sunspot periods, acting as a proxy to solar activity.
2. Correlation study indicates low but positive r-value exists between sunspot and extreme events. Some of the correlation coefficient obtained indicates insignificant because of its large p-value.
3. Lastly, the events of natural hazards are compared around sunspot maximum. The observation hints maximum drought occurrence in the growth phase of sunspot activity. The other events like flood, storm, volcano, seismic activity either they are antiphase with solar activity or lies at the declining stage of solar activity.

There are possible two mechanisms for the above investigation which can explain the connection between solar activity and extreme events like seismic activity. The first involves the change of solar activity causes irregular oscillations of the angular velocity of earth rotation, which result influences geo-extreme events. The second involves the connection between amplification of the solar activity and the perturbation of quasistationary state of the atmosphere, which leads to the redistribution of atmosphere mass on the earth that is centre of gravity motion of earth-atmosphere and consequently deformation of earth. Therefore, a link between solar activities with natural hazards like earthquake, volcanic activity is more or less significant. Therefore, the result obtained demonstrates a possible Sun-Natural hazards relationship and shows necessity of more detailed study in future.

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