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Trend of variable component of 10.7 cm solar flux during the period 1950-2014 and its association with the occurrence of major earthquakes

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सार – इस शोध पत्र में 10.7 सें.मी. सौर प्रवाह और बड़े भूकंपों (परिमाण ≥ 6.0 रिक्टर स्केल) के परिवर्तनीय घटक के बीच एक संबंध स्थापित किया गया है। वर्ष 1950-1962 और 1963-2014 की दो अवधियों के लिए 10.7 सें. मी. सौर प्रवाह के परिवर्तनीय घटक की भिन्नता का अध्ययन किया गया है। इन्हीं दो अवधियों के लिए 10.7 सें.मी. सौर प्रवाह के परिवर्तनीय घटक के साथ बड़े भूकंपों के समूह का भी विश्लेषण किया गया है। विश्लेषण से पता चला है कि बड़े भूकंपो (परिमाण ≥ 6.0 रिक्टर स्केल) की पुनरावृति 10.7 सें.मी. सौर प्रवाह के परिवर्तनीय घटक में कमी होने पर बढ़ जाती है और वृद्धि होने पर घट जाती है। इसमें संभावित स्पष्टीकरण भी प्रस्तुत किया गया है।

ABSTRACT. The paper presents a relation between variable component of 10.7 cm solar flux and major earthquakes (magnitude ≥ 6.0 Richter scale). Variation of variable component of 10.7 cm solar flux for two periods 1950-1962 and 1963-2014 is studied. Association of major earthquakes with the variable component of 10.7 cm solar flux for the same two periods is also analysed. Analysis shows that recurrence of major earthquakes (magnitude ≥ 6.0 Richter scale) increases with the decrease in variable component of 10.7 cm solar flux and vice versa. Possible explanation is also presented.

Key words – 10.7 cm solar flux, Earthquake, Sunspot number, Variable component, Solar cycle.

1. Introduction

Earthquake is a sudden trembling of the earth crust causing considerable hard to flora and fauna. It is a complicated, non-linear and irregular geophysical phenomenon. Earthquake generating processes are very complex and intricate that needs to be studied in comprehensive way associated with multi-disciplinary sciences (Mishra, 2012; Mishra, 2014). It is so because the physics of earthquake genesis is still not known completely with the present state of knowledge that makes the prediction of the earthquake impossible (Mishra, 2012). That is why the need of studying atmosphere and earth interactions arises. Earthquake is not only caused by internal effects such as subsidence, volcanic and/or tectonic effects but can also be triggered by some other external effects such as cosmic rays magnetic field and solar activities (Dorman, 2004; Gerontidou *et al*., 2002).

The sun emits radio energy with slowly varying intensity. The radio flux, which originates from atmospheric layers high in the sun's chromosphere and low in its corona, changes gradually from day to day in response to the number of spot groups on the disk. Solar flux from the entire solar disk at a frequency of 2800 MHz is a measure of the solar radio flux density per unit frequency at a wavelength of 10.7 cm, near the peak of the observed solar radio emission. It represents a measure of diffuse, non-radiative heating of the coronal plasma trapped by magnetic fields over active regions and is an excellent indicator of overall solar activity levels.

Till date earthquake is an unpredictable phenomenon and major problem for mankind. Scientists are trying to find more reliable earthquake precursors so that earthquake prediction may be properly possible in the near future. Several attempts have been made to find some relationship between earthquake and other physical activities like solar, geomagnetic, ionospheric activities etc. There are several works to link up between solar activity and occurrences of earthquakes. Nikouravan (2012) analysed the relationship between solar activities mainly sunspots number, solar 10.7 cm radio flux, solar irradiance, solar photon events and local earthquake in New Zealand. The study revealed that the maximum number of earthquakes occur frequently around the minimum years of solar activities, mainly during years of minimum sunspot numbers and during the years

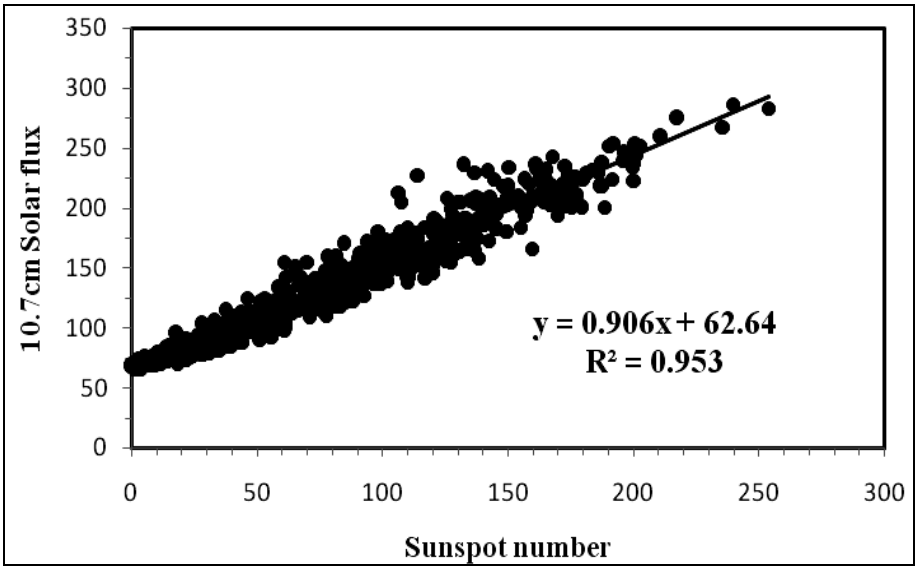

Fig. 1. Variation of monthly mean 10.7 cm solar flux with relative sunspot number from 1950-2008

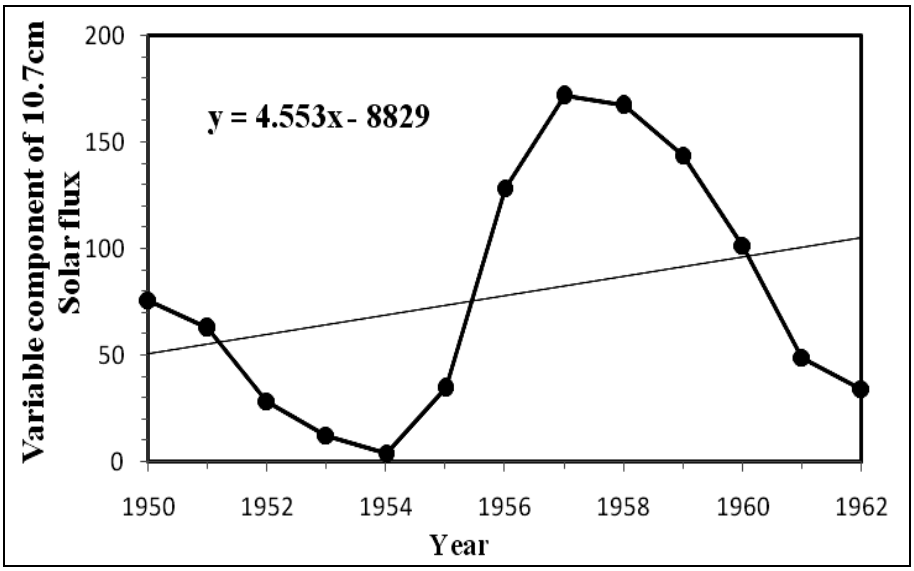

Fig. 2. Variation of variable component of 10.7 cm solar flux with year for the period 1950-1962

of minimum solar 10.7 cm radio flux with a strong correlation coefficient. Varotsos *et al*. (1992) explained the behaviour of the 10.7 cm solar flux, surface air temperature and sea surface pressure on the basis of the 11-year solar cycle and the Quasi-Biennial Oscillation (QBO) over Greece. Zhang (1998) established relations between sunspot numbers, solar proton events, solar 10.7cm radio flux and earthquakes ($M \geq 6$) and concluded that maximum earthquakes occur during minimum years of solar activity. The earthquake frequency in the minimum period of solar activity is closely related to the maximum annual means of sunspot numbers, the maximum annual means of solar 10.7 cm radio flux and solar proton events of a whole solar cycle and the relation between earthquake and solar proton events is the predominant one. Khodairy *et al.* (2015) analysed the relations between sunspot numbers and earthquakes ($M \geq 5$) and ($M \geq 8$), solar 10.7 cm radio flux and earthquakes, solar proton events and earthquakes, sunspots area and earthquakes during solar cycle 22, from 1986 to 1996 and found that there is an inverse relation between solar activity and earthquakes activity for $M \geq 5$ and a direct relation between solar activity and earthquakes activity for $M \geq 8$ during the maximum of

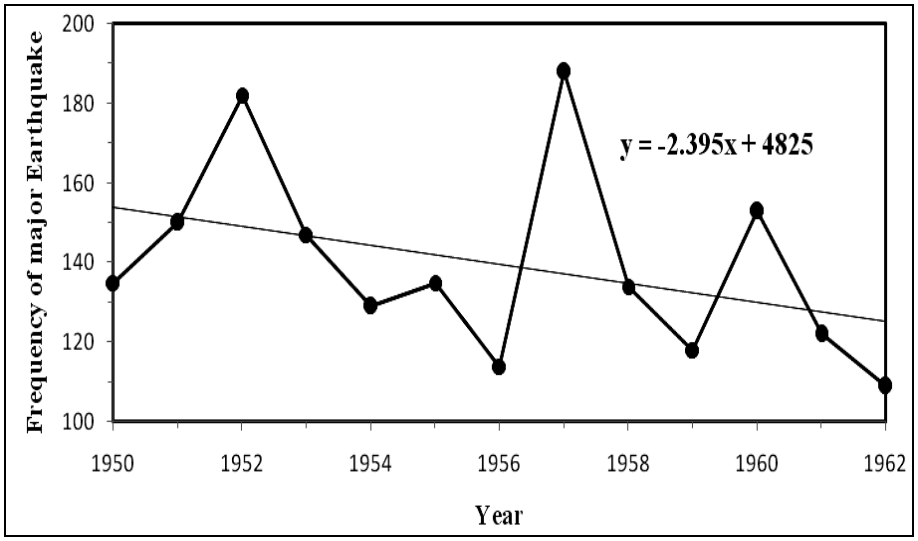

Fig. 3. Variation of major earthquake (magnitude ≥ 6.0 Richter scale) frequency with year for the period 1950-1962

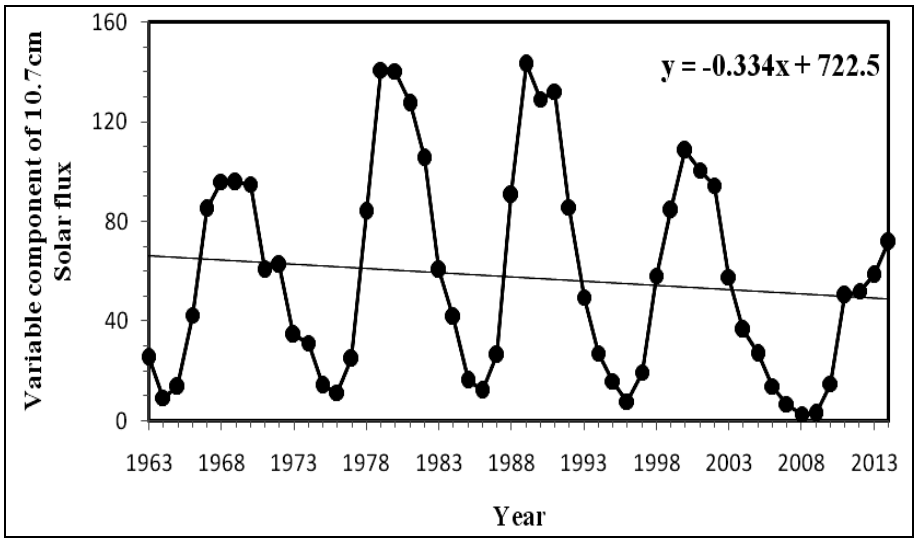

Fig. 4. Variation of variable component of 10.7 cm solar flux with year for the period 1963-2014

solar cycle 22 and an inverse relation between both at the descending phase of the same cycle. Nikouravan *et al*. (2012) studied the relationships between solar activities such as sunspots numbers (SNs), solar 10.7 cm radio flux (SRF), solar irradiance (SI), solar proton events (SPEs) and local earthquakes for magnitude ≥ 4, for Iran area from 1970 to 2010. Anti relation between solar coronal index and major earthquakes has also been recently reported (Midya *et al.*, 2016).

It has been previously investigated that variable component of several solar parameter, like variable component of 10.7 cm solar flux, plays a key role over its total component on the different atmospheric phenomenon. Midya and Saha (2011) also showed a significant co-variation between rate of change of Total Column Ozone (TCO) and summer monsoon rainfall with the increasing variable component of 10.7 cm solar flux. A significant result for airglow emission of 5893 Å line with the variation of variable component of 10.7 cm solar flux was also obtained (Midya *et al*., 1996). The variable component of 10.7 cm solar flux also plays important role on 6300 Å line emission (Midya *et al*., 1997). A critical analysis was done on the effect of the variable component

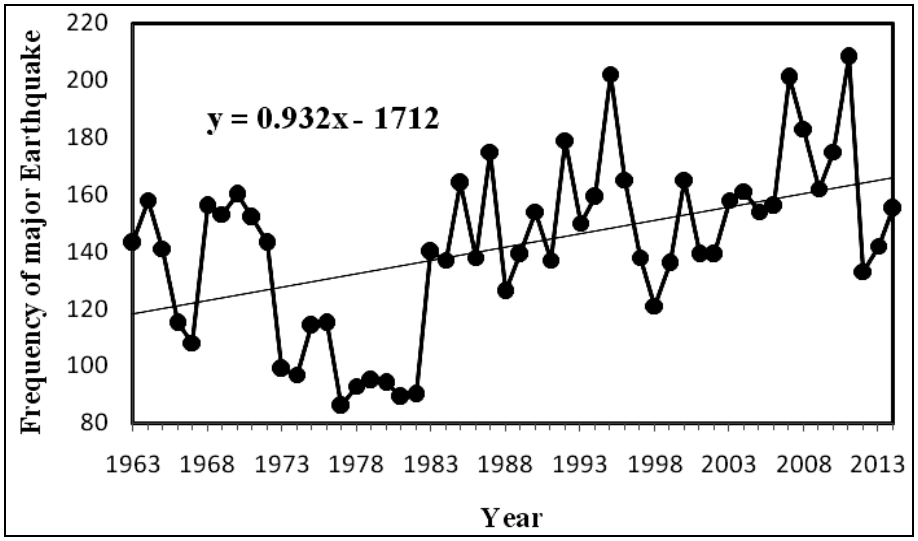

Fig. 5. Variation of major earthquake (magnitude ≥ 6.0 Richter scale) frequency with year for the period 1963-2014

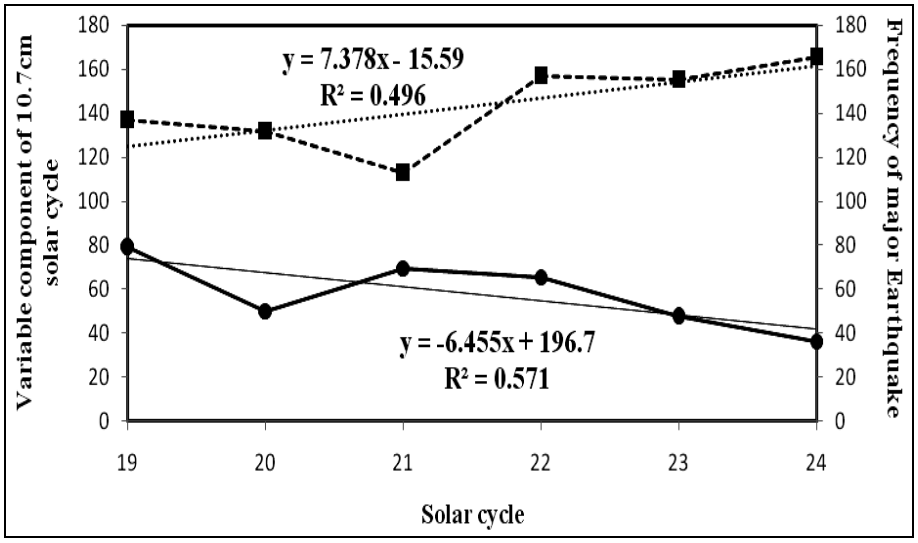

Fig. 6. Variation of total major earthquake (magnitude ≥ 6.0 Richter scale) frequency with the variable component of 10.7 cm solar flux for the solar cycle 19-24. [The circle represents the variable component of 10.7 cm solar flux for each cycle and the square represents the total major earthquake (magnitude ≥ 6.0 Richter scale) frequency]

of 10.7 cm solar flux on the pre-monsoon thunderstorm frequency over Kolkata (22°32′ N, 88°20′ E) and its relation with the ozone depletion mechanism by photo dissociation of nitrous oxide was also established for the period 1997-2008 (Saha *et al*., 2011).

Sun earth interaction on earthquake phenomenon is now a hot topic of research. In different publications the authors has considered total solar parameters. Variable of any solar parameter is more important than total component on different atmospheric and geophysical phenomenon. The purpose of this paper is to investigate the relationship between the variable component of 10.7 cm solar flux with occurrences of major earthquakes (magnitude ≥ 6.0 Richter scale).

2. Data and methodology

Data of major earthquakes (magnitude ≥ 6.0 Richter scale) from 1950 to 2014 are collected from the websites

TABLE 1

The total number of earthquakes in maximum and minimum years of variable component of 10.7cm solar radio flux

Solar cycle	Years of start and finish	Year of maximum variable component of 10.7cm solar radio flux	Year of minimum variable component of 10.7cm solar radio flux	Variable component of 10.7 cm solar radio flux	EF (≥6)
19	1954-1964	1957		172.0041	188
			1954	3.99395	129
20	1964-1976	1968		95.93785	156
			1964	9.2412	158
21	1976-1986	1979		140.67915	95
			1976	11.3703	115
22	1986-1996	1989		142.95925	139
			1996	7.85955	165
23	1996-2008	2000		108.2972	165
			2008	2.5972	183
24	2008-continue	2014		71.6797	155
			2008	2.5972	183

EF : Earthquake frequency

http://earthquake.usgs.gov. The daily data for the relative sunspot number and 10.7 cm solar flux adjusted to 1 AU are collected from the official website of the US National Oceanic and Atmospheric Administration (NOAA), ftp://ftp.ngdc.noaa.gov for the same period.

Variable component of 10.7 cm solar flux is calculated by plotting the relative sunspot number against the 10.7 cm solar flux (Fig. 1) for the period 1950-2014. Extrapolating to zero sunspot area, the line of the most probable relation between 10.7 cm solar flux and relative sunspot number, the basic component is obtained and it is the quiet sun emission. The emission above the base level is called the variable component of 10.7 cm solar flux. The variable component of 10.7 cm solar flux is computed from daily value of 10.7 cm solar flux, adjusted to 1 AU.

Graphical representation of earthquake frequency with year is done for major earthquakes (magnitude ≥ 6.0 Richter scale) throughout the world for time intervals, 1950-1962 and 1963-2014 and its variation with the variable component of 10.7 cm solar flux is also observed.

The maximum and minimum years for variable component of 10.7 cm solar flux is related with the major earthquake frequency for solar cycle 19, 20, 21, 22 and 23, with the solar cycle 24 being the incomplete one upto 2014 are presented in Table 1. For each solar cycle, the average value of variable component of 10.7 cm solar flux and total earthquake frequency is calculated and plotted to verify the result.

3. Results and discussion

The scatter plot of variable component of 10.7 cm solar flux is showing an increasing trend for the period 1950-1962 (Fig. 2), whereas the frequency of major earthquake (magnitude ≥ 6.0 Richter scale) is showing a decreasing trend for the same period (Fig. 3).

The variable component of 10.7 cm solar flux is showing a decreasing trend for the period 1963-2014 (Fig. 4) and the reverse is observed for the frequency of major earthquake (magnitude ≥ 6.0 Richter scale) for this period (Fig. 5).

The decrease in the frequency of major earthquake for the period 1950-1962 may be due to the strengthening of solar magnetic field thus weakening the magnetic field of the earth. The strengthening of solar magnetic field is clearly depicted from the increasing trend of the variable component of 10.7cm solar flux for this period. The increase in the frequency of major earthquake for the period 1963-2014 may be due to the weakening of solar magnetic field thus strengthening the magnetic field of the earth. The weakening of solar magnetic field is clearly depicted from the decreasing trend of the variable component of 10.7cm solar flux for this period.

The average value of variable component of 10.7 cm solar flux and total earthquake frequency is plotted for each solar cycle and it is found that in the minimum variable component of 10.7 cm solar flux, the total earthquake frequency is maximum (Fig. 6). This also verifies the result.

After Fourier analysis variable component of 10.7 cm solar flux shows a periodicity of 10.89 years which is approx to an 11years solar cycle.

4. Conclusions

It is observed that earthquake genesis processes are very complicated and it needs integrated study. Analysis shows an anti-correlation between trend of major earthquake frequency and that of variable component of 10.7 cm solar flux. Major earthquake frequency confirms decreasing trend from 1950 to 1962 and then from 1963 to 2014 shows an increasing trend. Earthquake is not only caused by internal effects such as subsidence and volcanic effects and/or tectonic effects but can also be triggered by some other external effects like solar activities and solar magnetic field (Midya and Gole, 2014; Midya and Panda, 2013). The probability of major earthquake increases when variable component of 10.7 cm solar flux decreases. It is expected that the decrease in variable component of 10.7 cm solar flux decreases the solar magnetic field and as a result magnetic field of earth becomes significant and free to displace tectonic plates. This may be a possible cause of increase of major earthquake with the decrease in the variable component of 10.7 cm solar flux. Thus solar activities can be a measure for earthquake. It is inferred that our results may be corroborated with other earthquake precursory study to arrive at common consensus on impact of solar flux on seismogenesis.

Disclaimer : The contents and views expressed in this research paper/article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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