

Study of Major Earthquakes (Magnitude ≥ 6 Richter Scale) with C_p Index During the Period 2001-2007.

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ABSTRACT

A critical study of variation of geomagnetic activity index C_p for the period 2001-2007 have been made and its close association with major earthquakes (magnitude ≥ 6 Richter scale) is also presented. From statistical analysis it is confirmed that when C_p attains the value 0, then the probability of the occurrence of major earthquakes is maximum. This is also explained considering the motion of the molten metal inside the outer core and inner core of Earth.

(Keywords: C_p index, earthquakes)

INTRODUCTION

Earthquakes are a major problem of mankind and until now have been unpredictable phenomena. Scientists are trying to discover more reliable earthquake precursors so that earthquake prediction may be possible in future. Some attempts are already taken by different scientist throughout the world.

Chakrabarti *et al.*, 2005 presented the observation of ionospheric variability by continuous monitoring of VLF signals during Sumatra-Andaman earthquake in 2004 and reported that the delay in sunset time occurred 24hrs prior to the occurrence of earthquake. Study of surface latent heat flux (SLHF) and night time sub-ionospheric low frequency (LF) radio soundings showed anomalous fluctuations before earthquake. Both SLHF and nighttime LF showed complementary nature with SLHF variations are prominent near the epicentral region of coastal earthquake (Cervone *et al.*, 2006).

Pulinets and Dunajcka (2007) reported from LAI (Lithosphere-Atmosphere-Ionosphere Coupling Model) and experimental data of remote sensing satellites that thermal anomalies due to radon emission in the area of earthquake preparative zone can produce variation of air temperature and relative humidity.

Ganguly (2009) reported that column ozone concentration over a location reaches its lowest value on the day of major earthquake, increase gradually after the calamity and attain its peak value. Afterwards ozone concentration was found to be normal. Quasi-static electric field anomaly in the upper ionosphere before an earthquake had been observed as an ionospheric precursor (Gousheva *et al.*, 2009). According to LAIC model (Lithosphere-atmosphere-ionosphere coupling model), geochemical, atmospheric and ionospheric parameters are united by a common physical mechanism (Pulinets 2009). Using IAP (ionospheric plasma analyzer) and ISL (Langmuir probe) on DEMETER satellite and GPS data analysis Akhondzadeh *et al.*, (2010) showed electron and ion density variations in the ionosphere occurred over locations prior to strong earthquakes.

Jain *et al.*, 2010 reported the anomalies in slab thickness of ionospheric F-region for some days before the main seismic event. They concluded that it may be due to the seismogenic electric field developed above the surface of the earth. Recent investigation has shown that major earthquake ($M \geq 6.0$ Richter scale) occurrence within 48hrs is expected when geomagnetic index K_p attains its minimum value (Midya *et al.*, 2011). The magnetic field of sun which is created due to solar flare interacts with the magnetic field of earth leads to some terrestrial phenomena such as –

geomagnetic storms, aurora, ionospheric absorption, airglow etc. Sarkar *et al.*, (1991) observed good correlation between quasi-periodic fading in the nighttime VLF and LF atmospheric with geomagnetic activity index. Sen *et al.*, (1967) also observed the association of the fading of VLF, IFIA (very low frequency, integrated field intensity of atmospheric) with the geomagnetic activity index.

It is now well accepted that the geomagnetic storm is produced by plasma cloud arriving at earth after a solar flare. In order to account for the sharp onset of magnetic disturbances of the earth, Gold *et al.*, (1995) suggested that it is due to a shock wave created in the plasma cloud. Geomagnetic control of 6300A⁰ night airglow emission from low latitude station (Mt. Abu, India) is reported by Kulkarni *et al.*, (1975). Mukherjee (1999) also reported the storm-associated variation of 6300 A⁰ emission from low latitude station, Kolhapur. The maximum enhancement of 6300 A⁰ line was observed during the period of high value of Kp index during night. Kp is one of the important geomagnetic activity index and data are available by the International Service of Geomagnetic Indices. Cp can be calculated from Kp.

The purpose of this paper is to study the variation of Cp index before, during, and after earthquake and possible explanation is also presented.

DATA AND METHODOLOGY

The website:

http://earthquake.usgs.gov/earthquakes/eqarchives/epic/epic_global.php

is used to collect major earthquake data (magnitude ≥ 6 Richter scale). Cp index is taken from Solar Geophysical Data, National Oceanic and Atmospheric Administration, Boulder, Colorado.

The planetary three - hour- range index Kp is the mean standardized k-index from 13 observatories between 44⁰ and 60⁰ northern or southern geomagnetic latitude. The scale is 0₀ to 9₀, expressed in thirds of a unit, e.g. 5- is $4\frac{2}{3}$, 5₀ is 5, 5+ is $5\frac{1}{3}$. So 0+ means $\frac{1}{3}$. 0 is considered for very quiet period and 9 is for extremely disturbed

period. This planetary index has been designed to measure solar particle radiation by its magnetic effects. The other index derived from Kp is the three – hour index ap. Cp is a qualitative estimate of overall level of magnetic activity for the day determined from the daily sum of eight ap amplitudes. Cp ranges, in steps of one-tenth, from 0 (quiet) to 2.5 (disturbed).

Graphical presentation of Cp index with major earthquakes throughout the world is done. Nature of motion of highly viscous liquid of outer core is studied. Physical explanation considering the motion of liquid between the inner and outer core is also presented. Test for equality of two population proportions and chi-square test are used to draw our conclusion.

RESULTS AND DISCUSSIONS

The Earth's magnetic field is believed to be generated due to spinning movement of molten metals inside the outer core of earth. Thus we can expect an association of disturbances created inside the earth's core affect the geomagnetic parameters. A few observations of variation of Cp index are shown in Figure 1. Arrow mark shows the time of occurrence of major earthquakes. We have obtained almost same type of observations during the period 2001-2007. In most cases we observed that major earthquakes occur when Cp minimum (i.e., zero). There are also some unexpected occurrence of earthquakes as shown in Figure 1.

Periodogram analysis of monthly values of Cp index solar flare index is done (Figures 2 and 3). It is clear from the figures that there is a 9 years periodicity in Cp index and in Solar flare index. Thus it may be concluded that Cp is controlled by solar parameter.

The internal structure of earth consists of four distinct layers: the crust, the mantle, the outer core and the inner core. It can easily be shown that the molten metal inside the outer core undergoes turbulent motion (Raynold's number $\sim 10^{15}$) and the upper surfaces (mantle and the crust) continuously vibrate causing earthquakes in large numbers. The major earthquakes may be linked to the disturbances inside the outer core with large magnitudes. Other than the turbulent motion as mentioned above, there is a velocity gradient of the molten metal inside the outer core.

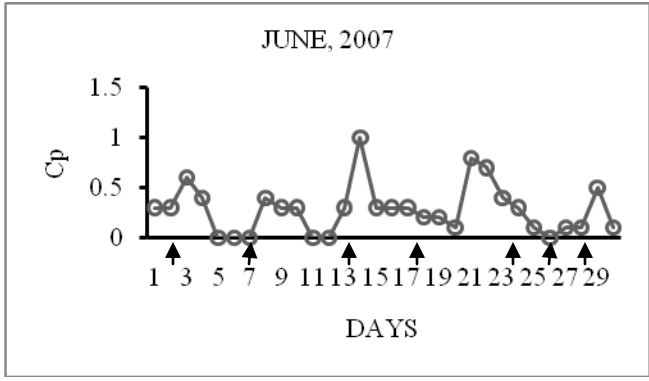
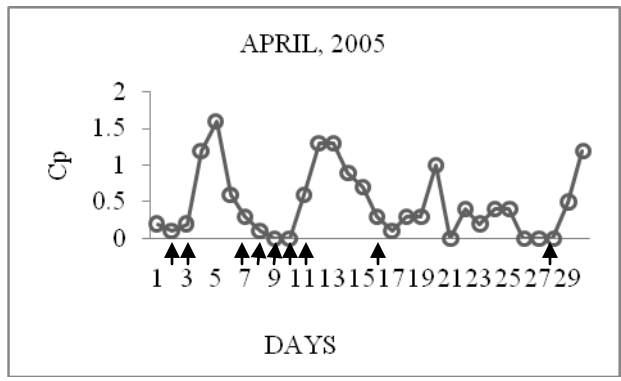
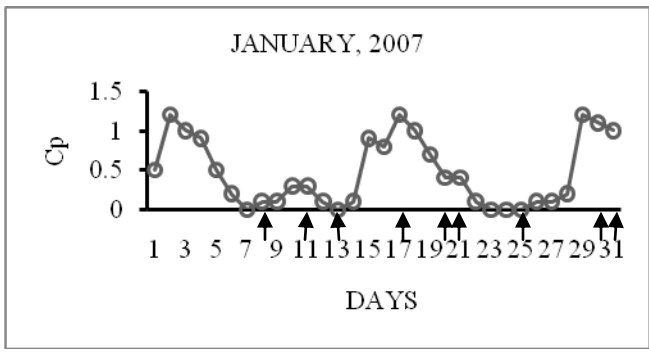
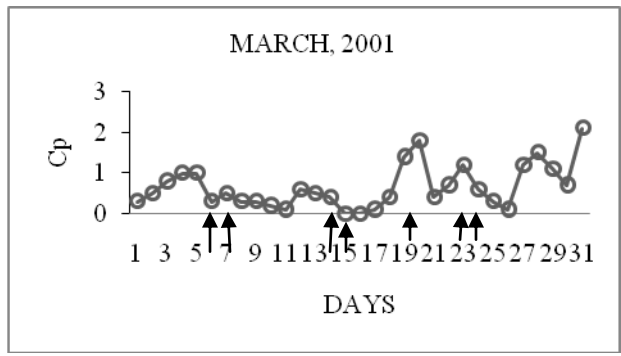
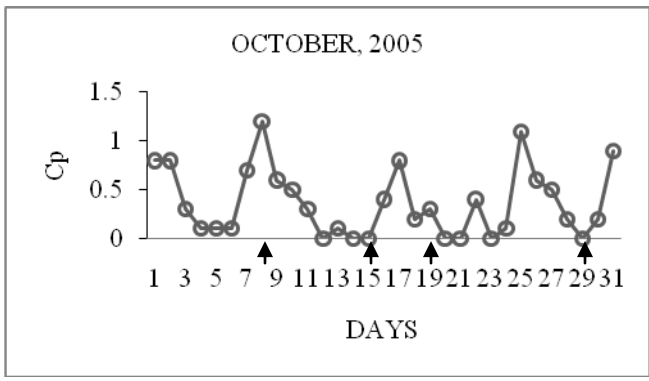
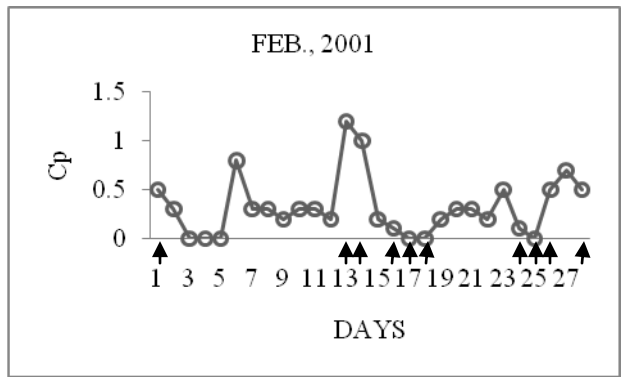


Figure1: Variation of Cp with Major Earthquakes.

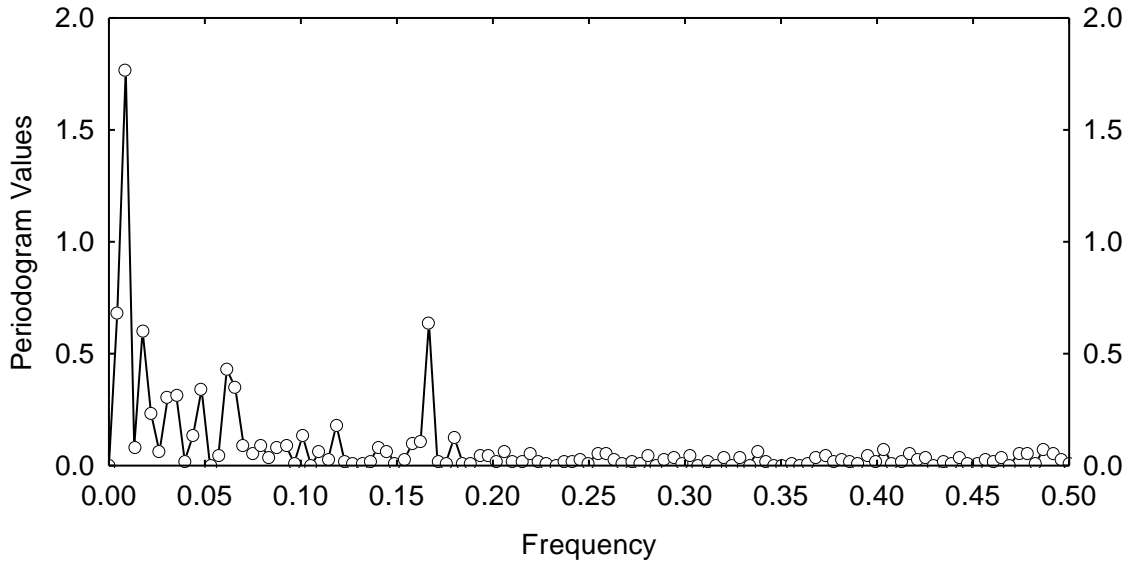


Figure 2: Periodogram of Geomagnetic Activity Index Cp from the Year 1989 to 2007.

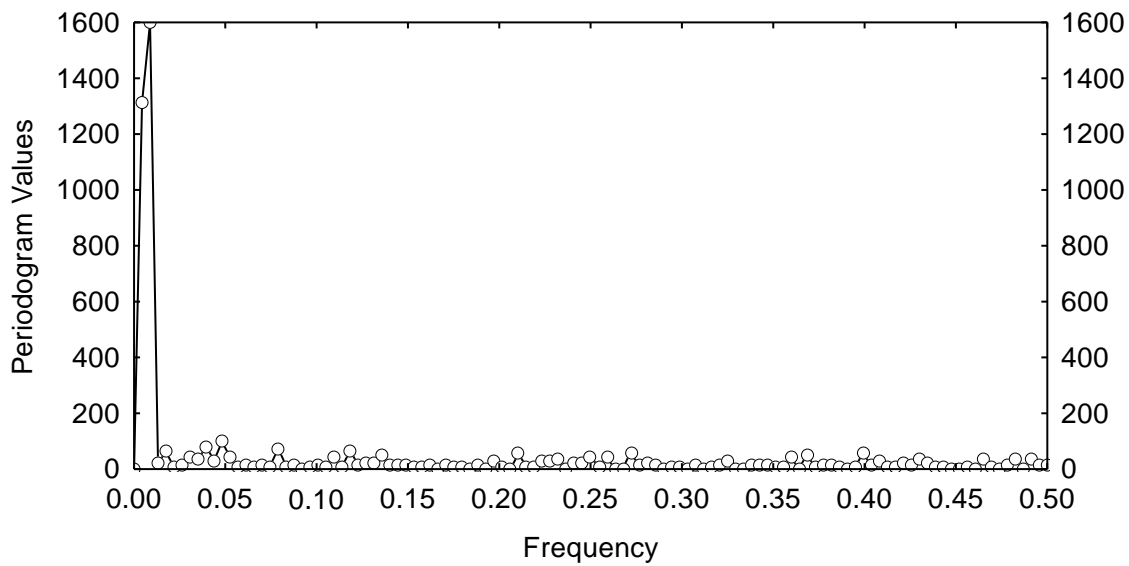


Figure 3: Periodogram of Total Solar Flare Index from the Year 1989 to 2007.

The layer in contact of the mantle of the outer core moves at a greater velocity w.r.to the layer in contact with the inner core. Due to the high viscous nature of material of the outer core, the layer in contact with the mantle will be dragged to some extent and then will break down causing a shear wave flowing towards the inner core. If we assume that the break down takes place for 10^0 angle of shear, simple calculation shows that the outer core is extended from 33^0 N latitude to 33^0 S latitude on the surface of earth. High frequencies

of such waves propagate and superimposes with one another producing beats. Thus there will be some stages where the disturbances are minimum and then grow to a large magnitude. The silent duration can be linked with Cp having minimum value. Therefore one can expect that right after Cp having minimum value, the disturbances inside earth's core starts to grow to larger values. It is believed that the motion of the outer core (which is partially ionized state) is the origin of earth's magnetic field. The magnetic

index, C_p depends on the earth's magnetic field and also on extraterrestrial events. A large value of C_p therefore not necessarily means that there is a disturbance in earth's magnetic field. However, the major earthquakes, as we observed is also present which are not right after C_p being minimum and that may be attributed to the fact that there is a large disturbance in the outer core due to some extraterrestrial events.

Our proposition is that earthquakes occur due to the turbulence motion of the liquid of earth's inner and outer cores. Therefore, one would expect major earthquakes just after C_p touches at minimum value.

ANALYSIS

Test for equality of two population proportions:

Let X_1 be the number of days with major earthquakes out of n_1 days when $C_p = 0$ and X_1 follows $\text{bin}(n_1, P_1)$ and X_2 be the number of days with major earthquakes out of n_2 days when C_p not equal to zero and X_2 follows $\text{bin}(n_2, P_2)$. P_1 & P_2 is the population proportion. Two populations are independent. Now, $n_1 = 257$ & $n_2 = 2299$. $X_1 = 145$ & $X_2 = 921$. Sample proportions are $\hat{P}_1 = \frac{145}{257} = 0.564$ & $\hat{P}_2 = \frac{921}{2299} = 0.401$.

Here, we want to test the hypothesis $H_0 : P_1 = P_2$ against the alternative hypothesis $H_1: P_1 > P_2$.

Here, we use the test statistic

$$\tau = \frac{\hat{P}_1 - \hat{P}_2}{\sqrt{\frac{\hat{P}(1-\hat{P})}{n_1} + \frac{\hat{P}(1-\hat{P})}{n_2}}} \text{ which follows under}$$

$$H_0, \text{ asymptotic } N(0, 1). \hat{P} = \frac{n_1 \hat{P}_1 + n_2 \hat{P}_2}{n_1 + n_2} = 0.417$$

$$\& 1 - \hat{P} = 0.583.$$

$$\tau = \frac{0.564 - 0.401}{\sqrt{\frac{0.417 * 0.583}{257} + \frac{0.417 * 0.583}{2299}}} = \frac{0.163}{0.031}$$

$$= 5.26$$

Tabulated $\tau_{0.05} = 1.645$. Since, calculated τ is greater than tabulated τ at the 5% level of significance, so, we can conclude, on the basis of the given data that H_0 is rejected i.e. the probability of the occurrence of the earthquake on the expected days (with C_p equal to zero) is greater than the occurrence on the unexpected days (with C_p not equal to zero).

Test of Independence

Here we want to test the hypothesis H_0 : Occurrence of earthquakes is independent with the different levels of C_p .

Cp Earthquake	Equal to zero	Not equal to zero	Total
Occurs	103 (a)	702 (b)	805 (a+b)
Not occurs	154 (c)	1597 (d)	1751 (c+d)
Total	257 (a+c)	2299 (b+d)	2556 (n=a+b+c+d)

$$\chi^2 = n \frac{(ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)}$$

n is the total number of days in the year 2001 – 2007.

Now, calculated chi-square is 9.757. Tabulated chi-square with 1 d.f. at 5% and 1% level of significance are 3.84146 and 6.63490. Since, at both the level of significance calculated chi-square is greater than tabulated chi-square, so, we can conclude that the occurrence of earthquakes are not independent with the different levels of C_p .

CONCLUSION

The surface of the earth is always moving with the rotation of the earth. The plates in contact with the outer crust of our earth are also in motion constantly. Whenever there is a differential movement between plates, there is bound to be a certain disturbance in the lithosphere and as a result earthquakes take place. Due to high Reynold's number (nearly equal to 10^{15}) the motion of highly viscous liquid of outer core is always turbulent. As a result, vibration is created in the mantle. This is highly attenuated when it reaches to the lithosphere of our earth. The amplitude of these vibrations is minimum and not significant. This is the source of production of earthquakes of smaller amplitude which are occurring in large numbers. The velocity of the highly viscous liquid layer in contact with the mantle is greater than the layer in contact with the inner core. As a result the highly viscous liquid is dragged to some extent and then breaks down. This produces shear waves and it moves towards the inner core. Beats are formed due to the superimposition of such waves of high frequency.

When beats are formed, the amplitudes of vibration become large and major earthquakes take place. Minimum disturbance of the molten magnetic material of the outer core produces minimum variation of magnetic index C_p which is equivalent to 0. Just after this minimum value, maximum disturbances take place due to formation of beat. As a result, major earthquakes occur. This agrees fairly well with our observations as presented in this paper.

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