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Sun-Earth-cosmic connection to understand early warning of Earthquakes

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Abstract

Muon detector has the potential to function as Nano Sensor to infer possible earthquake in earthquake prone areas. It has been observed that 30 to 36 hours before the occurrence of the earthquake the magnetic field (Kp) and electron flux (E-flux) of the Sun-Earth environment changes. Using Sun-Observatory-Heliospheric Observatory (SOHO) satellite data it is possible to monitor the fluctuation every 15 minutes interval. It has been observed that before the occurrence of earthquake, nanoparticle (muon) intensity reduces, while the atmospheric temperature rises along with the increase in Kp and E-flux values. After the earthquake the atmospheric temperature falls suddenly with the rise in cosmic rays and fall in Kp and E-flux values. It has been planned by IHY, NASA and UNBSS (United Nations Basic Space Sciences) to design and install basic hybrid SEVAN (Space Environment Viewing and Analysis Network) in 14 locations across the world. Cosmic Ray Division laboratory of Armenia will supply photomultiplier of similar standards to all these 14 locations including Jawaharlal Nehru University, New Delhi, India. These detectors will record and correlate the intensity of cosmic ray data to predict various environmental perturbations including earthquake. Based on this plan it was attempted to correlate Kp, Eflux and chages in environment in different locations across the world with variation of cosmic rays collected from existing muon detectors.

Introduction

Cosmic ray experiments are useful to detect the anomalous cosmic showers (Gupta *et al.,* 2005). High-energy galactic cosmic rays when strike Earth's atmosphere, they often produce a cascade of secondary sub-atomic particles called an "cosmic shower". An actual air shower may consist of millions of particles, depending on the energy of the initial cosmic ray. The SEVAN (Space Environment Viewing Network) project is world-wide network of Solar Neutron Telescopes. The SEVAN experiment was initiated at Argates mountain of Armenia by the director of Cosmic Ray Division, Ashot Chillingarian. The instrument will be placed in 14 locations across the world and planned to be named as Nano sensor for detecting the early warning of earthquake across the world. The nano sensor is formed from 4 separate identical modules, as shown in Fig. 1. Each module consists of standard slabs of 50x50x5 cm^3 plastic scintillators stacked vertically on a 100x100x10 cm^3 horizontal plastic scintillator slab (60 cm total thickness). One meter above the thick lower scintillator slab is another scintillator slab 100 x 100 x 5 cm^3, with the goal to register charged particles. A scintillator light capture cone and Photo Multiplier Tube (PMT) are located on the bottom and top slabs separately to measure the number of events in each of them. This collection constitutes one module.

Fig.1: Nano Sensor (Cosmic Ray Detector) for earthquake prediction

Incoming neutrons undergo nuclear reactions in the thick plastic target and produce protons and other charged particles. The intensity of the scintillation light induced by these charged particles has a dependence on the neutron energy and is measured by the PMT on the scintillators. It has already been attempted to correlate the variables of SOHO satellite data with the cosmic ray intensity before the occurrence of earthquakes and tsunami (Mukherjee, 2008).

Cosmic ray fluctuation and Sun-Earth connection in Earthquake Prediction

Earthquake and Tsunami prediction are the greatest challenges for the geologists since centuries. We are continuously collecting data for different environmental parameters. Sudden heat or cold waves, tornados, erratic rainfall and snowfall are being observed and their forewarning has been attempted (Mukherjee, 2006). Efforts have been made to understand the influence of stars and the Sun, which, although they are distant objects in space, can influence the environment of the Earth (Shaviv and Veizer, 2003). The effects of the Sun on the environment of the Earth were found to be modulated by the geomagnetic field and the ionizing potential of the cosmic rays (Marsh and Svensmark, 2000).During Earth directed CME a beam of electrons (plasma) is pumped towards the Earth. This beam of electrons is highly conductive and generates an electric field that is transmitted to Earth's natural plasmosphere and ionosphere (Mukherjee, 2001). This thin layer of changed electric field further influences the ionosphere and atmosphere of the earth. Since a beam of electrons is carried by an electric current, a magnetic disturbance would be produced. Starbursts cause the Sun to develop low Planetary Indices (Kp) and low Electron flux (E-flux) conditions for the Sun-Earth Environment (Lehtinen *et al.,* 1997; Fig.2).

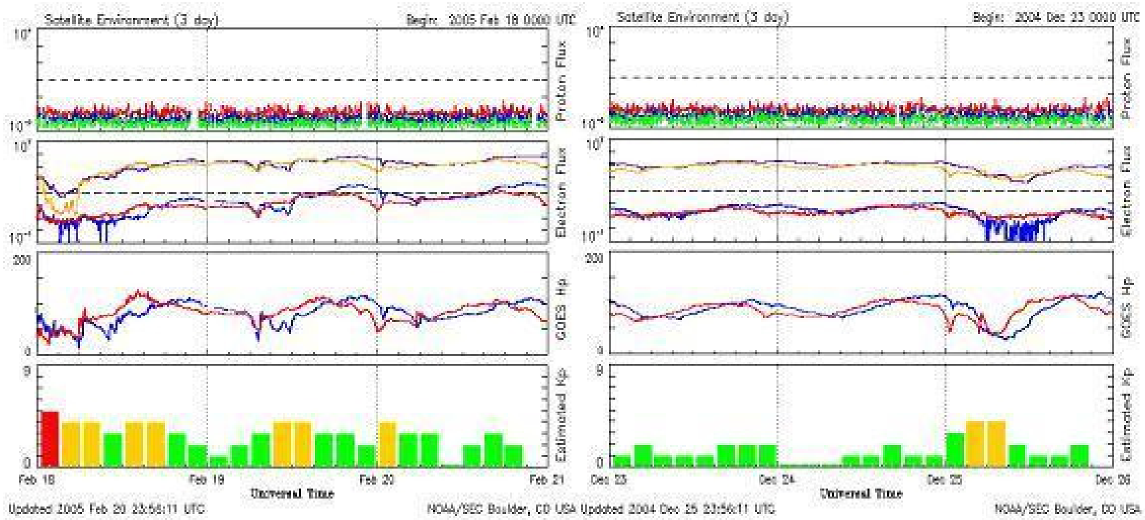

Fig. 2 : Fluctuation of electron flux and planetary indices (Kp) before earthquake

E-flux induces the variation of production of ionosphere currents. Ionosphere currents are produced by geomagnetic storms originating from the Star-Sun-Earth environment (Yu, 2004). Ionosphere current variation has a direct influence on atmospheric temperature (Viera and Da Silva, 2006). On 25th December 2004 and 23rd February 2005 hailstorms and snowstorms were reported in the Northern Hemisphere, while in the Tropics a sudden drop in temperature led to foggy and smoggy conditions. This temperature variation was different in different parts of the Earth, as the effects of solar flares are dependent on the geomagnetic co-ordinate of Earth and its respective position with regards to the stars. Further, the fluctuation of atmospheric temperatures in the month of December 2005, in the first week of January 2006 and in the last week of December 2007, suggests the direct correlation of the Cosmic-Sun-Earth environment (Fig. 3). If the electron flux from the sun is low, with the subsequent rise in cosmic rays simultaneously anomalous snowfall and lowering of the atmospheric temperature has been observed (Svensmark and Friis, 1997). It would be possible to understand the movement of clouds and snowfall, as well as atmospheric moisture, if we could efficiently calculate the influence of space weather and cosmic influence on the thermosphere and atmosphere of the Earth. Based on the same hypothesis it was found that an abnormal rise and sudden fall in E-flux, Kp index and atmospheric temperature has the possibility of triggering earthquakes in active fault areas of the Earth due to temporary changes in the magnetic field of the Earth. The whole process was expressed as a precursor of earthquakes in active fault areas.

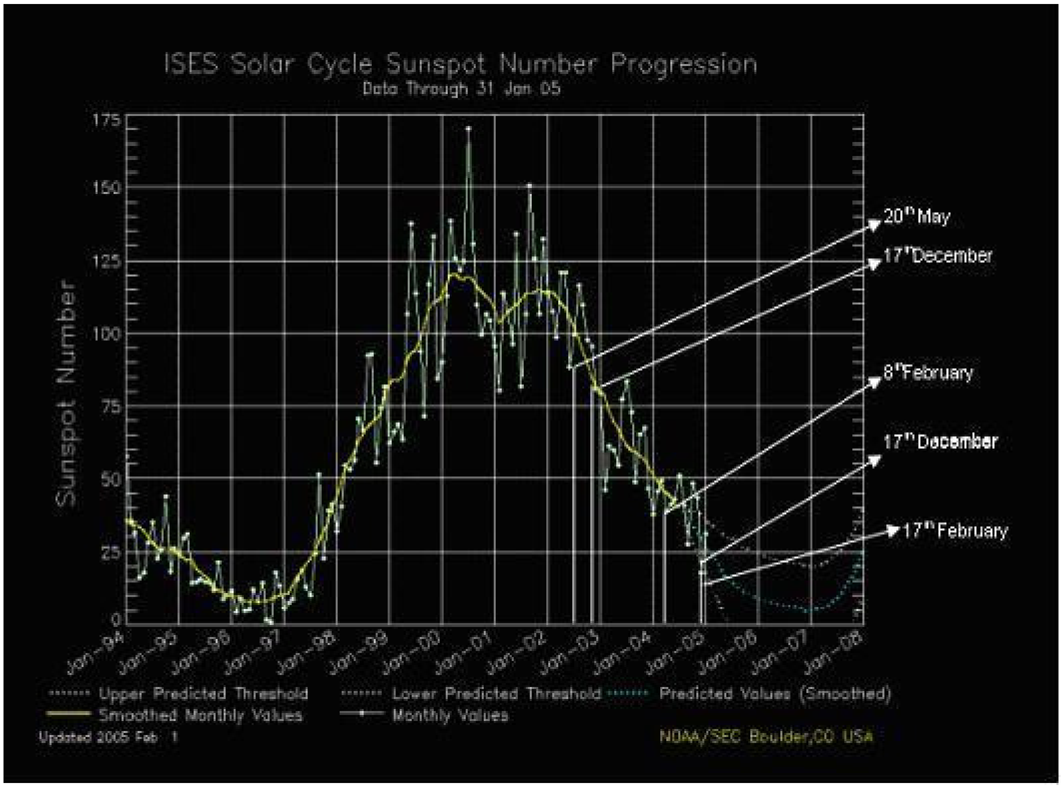

Fig. 3: Influence of monoceras star borne cosmic rays on Sun-Earth environment

The Sun-Earth environment has variables, which are changing on regular basis due to cosmic ray fluctuation. These variables are the Kp, proton flux and E-flux. Sudden changes in these parameters may abruptly influence the environment of the Earth. If an E-flux hike is responsible for global warming, then an E-flux lowering may lead to snowfall, thunderstorms and erratic rainfall. A severe geomagnetic storm originating from Sunspot No. 486, located in the southern part of the Sun, on 29th October 2003 has shown its effects on the environment of the Earth. It began at approximately 1,700 UT when a Coronal Mass Ejection (CME) originating from an X10-class explosion from giant sunspot 486 struck our planet's magnetic field. Proton flux, E-flux and planetary Kp indices showed a sudden rise from 17.00 UTC on 29th October. Proton flux was more than 10 4 Mev and electron flux jumped to 106 Mev, while Kp was at a peak value of 9. The effect of this CME was observed in crustal disturbances in seismically active parts of the earth. An earthquake of 6.8 on the Richter scale was recorded off the coast of Honshu, Japan on October 31. The Honshu area of Japan is on an active fault which makes it earthquake prone. The triggering of the earthquake is sometimes initiated by the change in the magnetic field in Sun-Earth environment which influences the faulting further. Before the occurrence of this severe earthquake a bright aurora was seen in the sky of Japan. It is possible to correlate the triggering of the active fault in the Honshu area of Japan with the sudden change in the magnetic shield of the earth due to the impact of CME from Sun. The effect of earth directed CME would not only trigger the earthquake, but affect the whole environment of the Earth, including the destruction of ozone layers leading to climate change. Active sunspots 487, 488 and 492, along with 486 in the southern part of the Sun, continued to pose a possible threat to the changes in the thermosphere, ionosphere, atmosphere and geosphere of the Earth.

The mechanism of the cosmic Sun-Earth connection on environment of the Earth has been established by correlation studies of cosmic ray variation with geophysical variables of the Sun. The effect of Earth directed Coronal Mass Ejections (CME) from the Sun reveals a sensational impact on the atmosphere and geosphere. It has been observed that there is a close relationship between Kp values (Planetary Indices) and particle flux (Electron flux and Proton Flux) with the CME. The response of the magnetosphere to interplanetary shocks or pressure pulses can result in sudden injections of energetic particles into the inner magnetosphere. It has been recorded that, 36 hours before the occurrence of an earthquake, Kp values and E-flux increase drastically. The phenomenon was recorded during the Kutch, Gujarat, earthquake of 2001. Before the Occurrence of this catastrophic earthquake of Kutch, Gujarat India the cosmic ray has shown anomaly before 70 hours of triggering of earthquake on 26th January 2001. The cosmic ray intensity was found at its record low count from 10,000 counts per second to a few hundred only (Fig.4). The changes in the particle flux depend on changes in magnetic and electric fields. Particle flux from the Sun can suddenly change the Kp (Planetary Indices), which may be directed towards Earth in the form of magnetotail. Interaction of the CME particles with the ionosphere, Earth's upper atmosphere (between 80 and 200 km above the ground), has been noticed. Scientists doing research with magnetometers just before major earthquakes have serendipitously recorded tiny, slow fluctuations in Earth's magnetic field. Satellites equipped with IR cameras could be used to detect seismic hot spots from space. In fact, when Freund and Ouzounov of the Goddard Space Flight Center (GSFC) examined infrared data collected by NASA's Terra satellite, they discovered a warming of the ground in western India just before the powerful January 26, 2001, earthquake in Gujarat. Before the earthquake anomalous radiowave propagation was also observed.

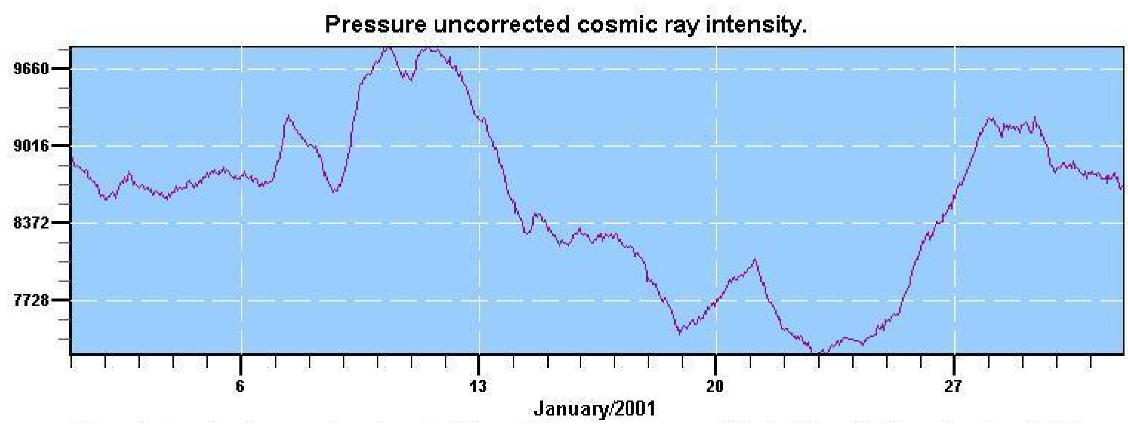

Fig. 4: Anomalous low cosmic ray intensity 70 hours before the occurrence of Kutch (Gujarat), India earthquake of 26th January, 2001

Radio wave propagation (*e.g.* ionospheric "whistlers"), which appears to play a role in earthquakes, and it can be studied by closely monitoring the impact of the solar wind on the ionosphere (Siingh *et al.,* 2005). We are interested in the sun because of the many influences it has on our lives and our environment (Tsrutani *et al.,* 2003). Beyond the obvious considerations of heat and light, some examples of these direct and indirect solar influences are the effects on short-wave radio communications, navigation, use of satellites for communication and navigation, hazards to humans and instruments in space, electrical power transmission, geomagnetic prospecting, gas pipeline monitoring, and possibly weather, seismotectonics and human and animal behavior.

Earthquake lights have been reported before the Matsushiro swarms during the year 1965 to 1967 and before some recent earthquakes in China. During the Pattan earthquake (Pakistan) of December 1974, reliable forest officers and doctors far away from the earthquake epicenter observed earthquake lights coming from the sky. Before the occurrence of the Jabalpur earthquake (India) of 1997 a light source came from the sky before the occurrence of the earthquake. Experiments have been conducted at the University of Western Ontario, London (Canada) to understand the possible mechanism of earthquake lights. It has been suggested that adsorption of condensation of water could be thought of as an energy source for the release of light from solid particles suspended in a cooling column of air above ground. But this theory could not explain the occurrence of light from the sky.

The particles that enter from the magnetotail travel toward the Earth and create the aurora oval light shows. Dangerous particles are not able to penetrate to the Earth's surface but are forced by the magnetic field to move around the Earth. Particles gain entry through the cusps that are shaped like funnels over the polar regions or they gain entry far downstream from the Earth. The particles that enter downstream travel toward the Earth and are accelerated into the high-latitude ionosphere and produce the auroral oval light shows. Since the most intense auroras occur at solar maximum, it was once thought that the Sun hurled material out during these raised times of solar activity and that that material funneled directly into the polar cusps. However, we now understand that the electrons that cause the auroras come in downstream or from the Earth's magnetic tail. These electrons that enter at the magnetotail are energized locally within the magnetosphere. The solar wind, emanating from the Sun, injects plasma into the magnetosphere and transfers energy to it. Several times a day, the magnetosphere undergoes a disturbance called a substorm. As the substorm grows, most of the solar wind energy is dissipated within the magnetosphere, ionosphere and upper atmosphere.

This disturbance ultimately causes auroral displays, the acceleration of charged particles to high energies, the emission of intense plasma waves and electromagnetic waves, and the generation of strong ionospheric currents that produce significant changes in the upper atmosphere. These waves and currents often result in severe problems on Earth with communications, power supplies, and spacecraft electronics.

Other higher energy particle radiation that could pose a danger to life here on Earth is forced to drift around the Earth within two large donut-shaped regions called the radiation belts. Invisible magnetic fields are the reason that particle radiation moves in this way. Before the occurrence of the catastrophic earthquake on 26th January 2001 at Kutch, IMAGE spacecraft captured an invisible magnetic tail at Gujarat, India. This is a major precursor of the earthquake. More advanced researches Sun can charge the magnetosphere with energy, generating magnetic storms that occasionally may affect the active faults in igneous/sedimentary/metamorphic geosphere and change its viscosity to trigger the shallow focus earthquake. It may be interesting to observe the series of Earth directed Coronal Mass Ejections and the occurrence of earthquakes globally. It is not a specular correlation that an earthquake of 6.0 magnitudes that occurred on 11th August 2003 at Andaman Island of Indian subcontinent was preceded by a rise in Kp indices, Electron flux as well as X-ray flux. Cosmic ray variation before snowfall and subsequent earthquake on 8th October 2005, near India-Pakistan border and Kashmir Himalayas establishes fore bush effect and its relation with environment of the Earth (shown in between 8000 to 8100 particle (cosmic ray count) as low during earthquake and 10740 as high after earthquake (Fig.5).

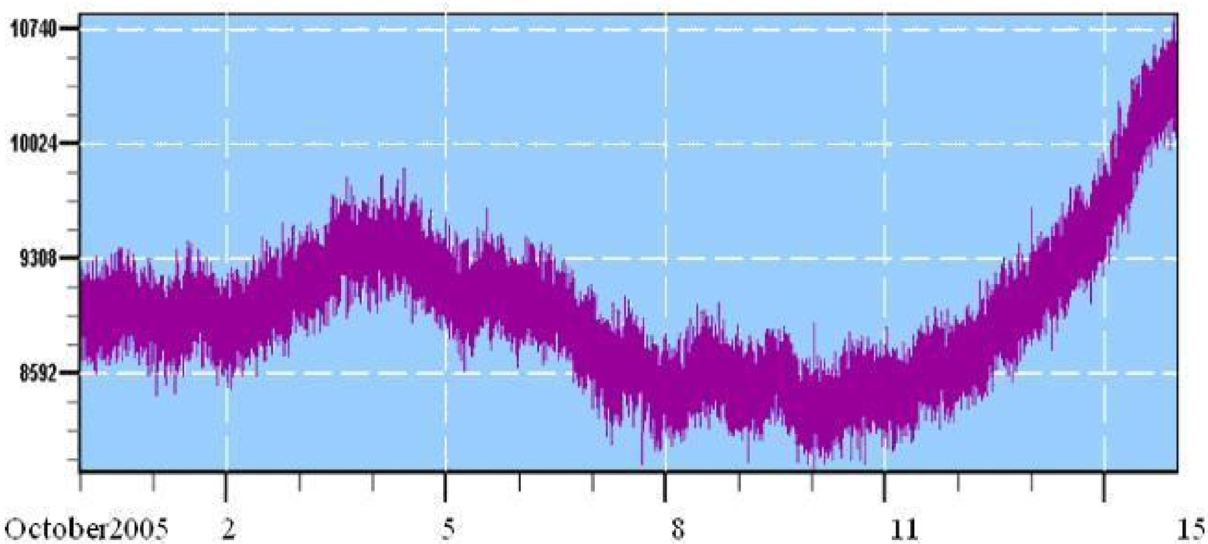

Fig.5: Low cosmic ray intensity before earthquake of Pakistan-India border on 8th October, 2005

Table-1: Sudden snowfall and rainfall after the rise in temperature in higher altitude and latitude on 25th December 2004 before the tsunami and earthquake in Indonesia. (This observation has been recorded across the world including Europe, Asia and USA. http://news.bbc.co.uk/2/hi/uk_news/4124715.stm#)

Location	Snowfall/Cold wave	Anomalous	Remarks
Liverpool (UK)	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Birmingham (UK)	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Manchester (UK)	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Cardiff (UK)	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Aberdeen (UK)	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Belfast	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Crosby	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk
Woodford	Snowfall	Yes	Low Kp and Low E-flux http://www.metoffice.gov.uk

Houghton, Michigan USA	Anomalous Snowfall	Yes	Low Kp and Low E-flux 4-5 inches of fresh snow http://www.americanoakresort.com/trailold2004.htm
Louisiana, Texas USA	Very high Snowfall	Yes	Low Kp and Low E-flux http://en.wikipedia.org/wiki/2004_Christmas_Eve_Snowstorm
Galveston, Texas, USA	Very high Snowfall	Yes	Low Kp and Low E-flux http://www.hprcc.unl.edu/nebraska/december25-2004.html Portions of South Texas have their first White Christmas ever as snow amounts measured from 1.5" in Brownsville to over one foot in Victoria
New York, USA	Very high Snowfall	Yes	Low Kp and Low E-flux http://en.wikipedia.org/wiki/2004_Christmas_Eve_Snowstorm
Queensland, Australia	Cyclone with cold wave	Yes	Low Kp and Low E-flux http://en.wikipedia.org/wiki/2004
Jammu Kashmir, Shimla, India	Snowfall with cold wave	Yes	Low Kp and Low E-flux http://en.wikipedia.org/wiki/December_2004#December_25.2C_2004

Source: Meteorological Office United Kingdom, BBC weather News UK and NOAA USA.

Table-2: Starbursts lower the temperature of earth. Forbush effect lowers the E-flux from Sun followed by a fall in atmospheric temperature. Source: NCDC USA and Messier catalog.

S.No.	**Starburst year**	**Star ID number**	**Anomalous fall in temperature**
1	1885	M31	Yes
2	1909	M101	Yes
3.	1914	M100	Yes
4.	1923	M83	Yes
5.	1926	M61	Yes
6.	1945	M83	Yes
7.	1950	M83	Yes
8.	1967	M99	Yes
9.	1969	M49	Yes
10.	1972	M99	Yes
11.	1983	M83	Yes
12.	1986	M99	Yes
13.	1988	M58	Yes
14.	1989	M58	Yes

15.	1989	M66	Yes
16.	1999	M88	Yes
17.	2004	M60, V838	Yes

Conclusion

It can be concluded that a sudden l drop in Kp and Electron flux, is an indication of atmospheric disturbance before occurrence of earthquakes in earthquake prone areas (Fig. 2). This hypothesis was supported by the event of erratic rainfall and snowfall before earthquake in India Pakistan border on 8th October 2005. Due to low Electron flux the local drop in temperature in the upper part of atmosphere leads to condense the clouds on the affected part of the earth.

Further, on 25th December 2004 and 23rd February 2005 hailstorms and snowstorms were reported in the Northern Hemisphere, while in the tropics a sudden drop in temperature led to foggy and smoggy conditions. An earthquake measuring 9.0 of Richter scale on 26th December followed the sudden changes in the environment. An earthquake measuring 6.4 on the Richter scale occurred on Tuesday 22 February in Zarand, Kerman Province (750 KM south-east of Tehran) at 05:55 local time. Weather condition in this region was difficult as there was heavy snowfall, resulting in a number of road blockades (Table-1).

Here I show a theoretical correlation between Starbursts, Solar minimum, Sun-Earth environment, snowfall and earthquake. The permanent component of cosmic radiation comes from the galaxy. It consists of very highly charged particles ejected by the gigantic explosions of supernova, massive stars that have reached the end of their days. These particles are atoms, which have been stripped of their electrons because of the temperatures within these giant stars. We see that during periods of high solar activity, the cosmic radiation is less intense, as the cosmic effect suppresses the formation of sunspots. During the impact of cosmic rays with the atmosphere of the Earth, ionization takes place. During this ionization the thermal energy is utilized to produce a regional fall in the temperature of the earth, which may lead to sudden snowfall in higher latitude and altitudes of the Earth (Mukherjee, 2007).

The magnetic field around the Earth protects the planet from cosmic rays. This field is stronger when the Sun is more active *i.e.,* emitting more ultraviolet radiation and displaying more sunspots hence fewer cosmic rays can penetrate Earths atmosphere. A direct influence of cosmic rays with the fall in temperature of whole world was observed during the years of starburst (Table - 2). A correlation between the global average of low cloud cover and the flux of Galactic cosmic Rays incident in the atmosphere has been observed (Fig. 3). Using data derived from International Satellite Cloud Climatology Project (ISCCP) and ground based diffuse solar radiation data provide a new evidence for a non linear effect of galactic cosmic rays on environment of the earth. It has been observed that during Forbush events simultaneous decreases occur in the diffuse fraction. Thus, cosmic ray variations are possible to correlate with geomagnetic storms, which changes the ionospheric currents and triggering of seismic activities in earthquake prone areas.

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