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Effect of Solar Flare and Coronal Mass Ejection in our Earth

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Abstract

As we know sun is a prime source of life for our earth so it is very important to know all activities of the sun and hazard occurred by it. Sun contains enormous amount of energy in the form of electromagnetic spectrum, particles, electrons, ions, gases, atoms and plasma. Time to time they emit tremendous amount of energy and matter into the interplanetary space which create space weather and affect the other planets in the interplanetary space. A number of phenomena are continuously occurring day and night which is the source of space weather such as prominence, solar flares, coronal mass ejection (CMEs). Sun continuously released energies, energetic particles and plasma in the interplanetary space in all the directions. Sun's atmosphere is divided into three main layer (1) photosphere (2) chromosphere (3) and corona. Many activities continuously occurring into these layers, as solar flare and CMEs are one of these. Although not all the solar flares are affecting our earth's atmosphere but only some of those whose intensities are high like M-class and X-class solar flares.

How Does the Solar flare and CME affect the Earth?

The Sun affects the Earth through two important mechanisms. The first mechanism is the sun's energy. The solar flare is a localized explosive release of energy, high energetic particles and protons that appears as a sudden, short lived brightening of an area in the chromosphere. Flares are rarely visible in white light that is emitted at the photospheric level but visible in EUV and X-ray wavelengths, i.e. emitted at the chromospheric level they display enormous release of energy and produce structural changes. In the radio region, (i.e.

at radio wavelengths) their effect is marked by various types of emissions. Solar flares release their energy mainly in the form of electromagnetic radiation and energetic particles. These X-ray and EUV waves travel at the speed of light, taking only 8 minutes to reach us here at Earth. The energy released in the process of solar flares increased the velocity and acceleration of solar wind which is affecting the space weather.

The second mechanism in which the Sun affects Earth is through the impact of matter from the Sun. Plasma, or matter in a state where electrons wander freely among the nuclei of the atoms, can also be ejected from the Sun during a solar disturbance. This "bundle of matter" is called a CME.

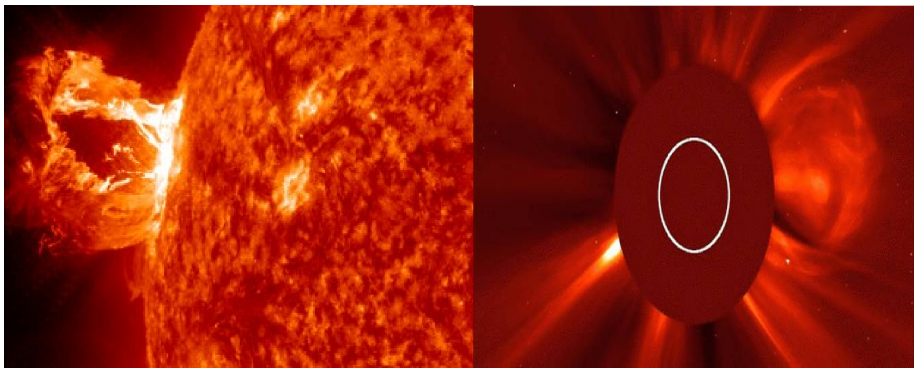

FIG. 1: Left:- solar flare, right:-Coronal Mass Ejection observed by LASCO/SOHO.

CMEs flow from the Sun at a speed of over 2 million kilometers per hour. It takes about 18 to 72 hours for a CME to reach us from the Sun. Since CMEs are large masses of ionic particles moving through interplanetary space, their energy is kinetic. The kinetic energy of a CME is around 10^{23} to 10^{24} Joule (Vourlidas et al., 2002).It has been shown that solar flare are not the necessarily drivers for CMEs (Kahler 1992). More powerful flares are generally associated with CMEs (Andrews 2003). CMEs do not necessarily need to correspond with flaring, although nearly all powerful (X or M class) flares have an associated CME (Andrews 2003, Yashiro et al. 2005). The larger flares tend to be associated with CMEs, but for even X-class flares about 10% of them lacked CME association (Gopalswamy et al. 2008). When a CME impacts the Earth's magnetosphere, it temporarily deforms the Earth's magnetic field, and inducing large electrical ground currents in Earth. Explosion powered by the sun's magnetic field (flares and CMEs) are the principal causes of space weather (Space Studies Board 2008).

Space weather affects our life in many ways such as they can change our environments, produce disturbances in our communication systems. As we know today we are totally depend on communication systems without it we cannot think about life. The source of communication system depends on satellites and earth's ionosphere where from high frequency wave propagation possible, both are influence by space weather. They may damage solar cell of satellites by solar flare protons, create plasma bubbles in earth's ionosphere affect astronaut safety, radio wave disturbance, signal scintillation, airline passenger radiation which goes through auroral region, electricity grid disruption, telecommunication cable disruption, earth current etc. (see figure 2.)

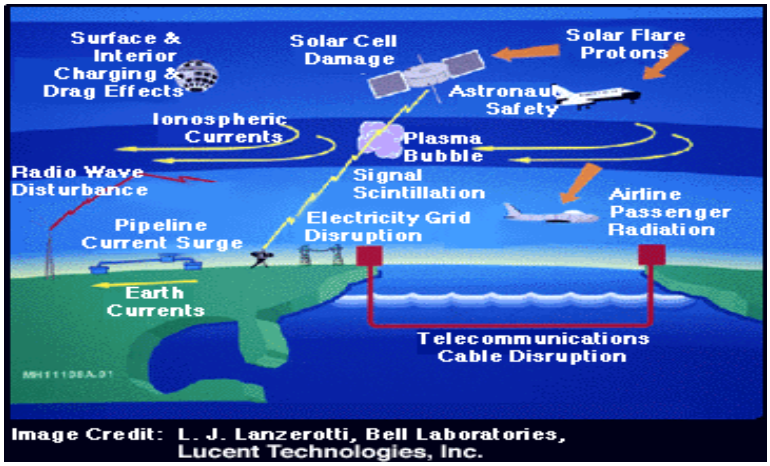

FIG. 2: space weather effect on our communication system

Here I try to explain some different types of hazards occurring by solar flare and CME on our earth.

Effect on magnetosphere

Our earth is a permanent magnet and their shield around the earth is termed as magnetosphere. The regions of magnetosphere shown in the figures in terms of their magnetic field lines originate from the northern hemisphere and terminality towards the southern hemisphere. Most of the solar wind speed is supersonic and superalfvenic. Solar wind exerts a pressure on earth's magnetosphere which compresses magnetic line of force as

a result earth facing towards the sun developed a bow shock whereas on the other side also developed magnetotail.

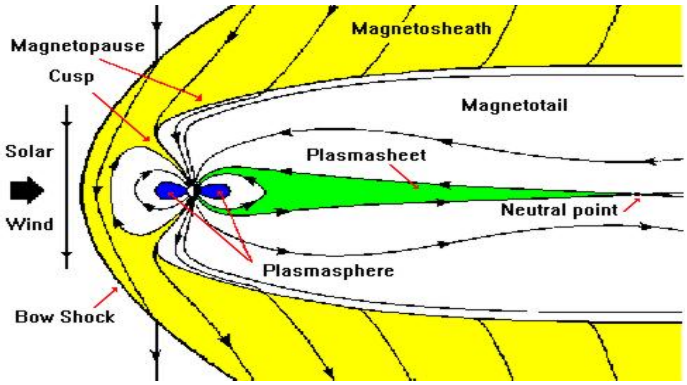

FIG. 3: Earth's Magnetosphere.

When the solar wind strikes on earth its kinetic energy converts into thermal energy. These energy flows behind the bow shock and make Magnetosheath. The area between the magnetosphere and magnetosheath is Magntopause (see figure 1). CME carry energetic particles, plasma and magnetic field of sun. When these CME pass near the earth the magnetic field of sun contained by CME is combined with magnetic field of earth. As a result both magnetic fields are joined together and this joining is called magnetic reconnection. This joining is very strong when field are antiparallel. This magnetic reconnection plays a key role for disturbance in earth's atmosphere. Plasma and other energetic particle inter through this reconnection and reach the earth's atmosphere and responsible for disturbances in ionosphere and communication media.

Effect on ionosphere and communication system

Ionosphere is the outermost layer of earth's atmosphere. It consists of several layers at different heights. At the day time it divided into D, E, F1 and F2 layer with different densities of ionization and at night F1 and F2 layer combined together and form a single layer F (see figure 4). As I said in my previous article (Prasad et al. 2006) each layer has its own properties, and the existence and number of layers change daily under the influence of the Sun. During the day, the ionosphere is heavily ionized by the Sun**.** During the night hours the cosmic rays dominate because there is no ionization caused by the Sun (which has set below the horizon).

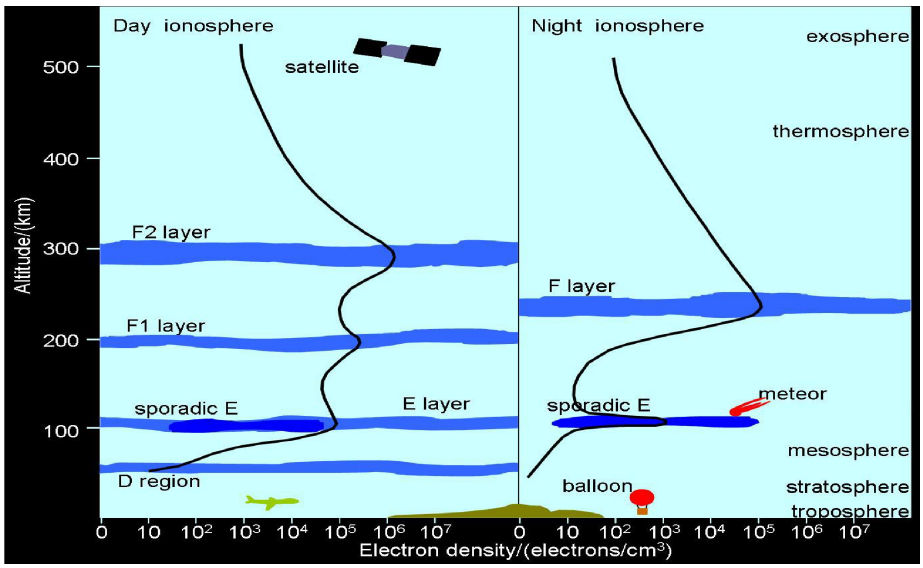

FIG. 4: The Earth's Ionosphere

Thus, there is a daily cycle associated with the ionizations. In addition to the daily fluctuations, activity by the Sun can cause dramatic sudden changes to the ionosphere. Wireless communications are used by military, police and other agencies in our India and other nations are also affected. The frequency used for wireless communication is kHz to MHz's. When energy from a solar flare or other disturbance reaches the Earth, the ionosphere becomes suddenly more ionized. Thus, changing the density and location of layers and free electrons in the ionosphere has a strong influence on the propagation of radio signals. Radio frequencies of very long wavelength (very low frequency or "VLF") "bounce" or reflect off these free electrons in the ionosphere thus, conveniently for us, allowing radio communication over the horizon and around our curved Earth. The strength of the received radio signal changes according to how much ionization has occurred and from which level of the ionosphere the VLF wave has "bounced" (Prasad et al. 2006).

Effect on Electric Grid

CMEs carry magnetic field of sun with him. When this magnetic fields move near the conductor such as a wire, a geomagnetically induced current (GIC) is produced in the conductor. The GIC is a

direct current (DC). The main cause of GICs is the interaction of the geomagnetic field with the magnetic field carried by CMEs and magnetized solar wind. These GICs is the main cause of disturbance in power grid. Within the electric power system, GICs can cause transformers to operate in their nonlinear saturation range during half of the AC cycle. The consequence of half-cycle saturation includes distortions of the voltage pattern (reflected in the existence of harmonics to the primary frequency), heating within the transformers, or voltage-to-current phase shifts expressed as reactive power consumption in the system (Carolus et al. 2013). The most famous GIC event occurred in Hydro-Quebec power plant in Canada on March 13, 1989, the electrical supply was cut off to over 6 million people for 9 hours due to a huge geomagnetic storm (Kappenman & Albertson 1990).

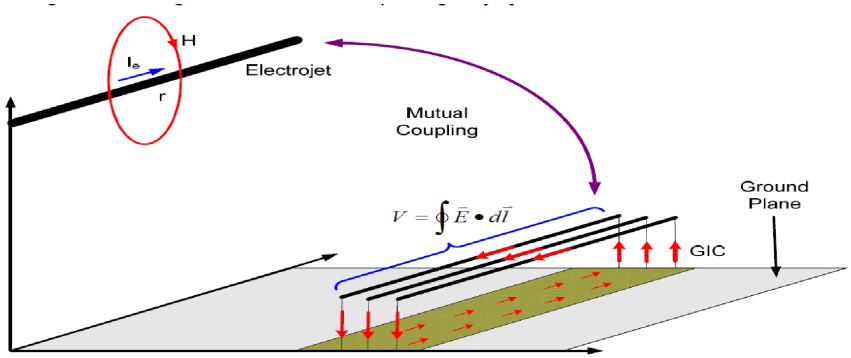

FIG. 5: Geomagnetic effects on power grid.

Effect on gas pipelines

They may also affect the gas pipelines. As we know gas pipelines are constructed by steels and coated by corrosion resistance coatings. The liquid or gases stored in it are under high pressure. For minimizing corrosions cathodic protection is used by keeping the negative potential with respect to the ground. GIC cause swings in the pipe-to-soil potential and increase the rate of corrosion during major GSs (Gummow 2002).

Effect on human body

The energetic particles can pass through the human body and causing biochemical damage. Due to the radiation risk increase the possibility of occurrence of cancer and some other deceases. Astronauts are mostly affected by this if they are not well protected.

Formation of aurora

FIG. 6: Aurora

When a charged particle emitted from the sun reached in earth's atmosphere they collides with gas particle of atmosphere as a result a coloured pattern is formed. Aurora is visible at high latitudes. The colour pattern is depending on flow of charged particles and magnetic field in it. Oxygen molecules produce green and red colours while nitrogen molecules produce purplish-red and blue colours pattern.

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