International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Solar Intensity Variation due to Coronal Mass Ejection Over a Long Range Time Period

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Abstract: ***Earth system processes (ESP) are interrelated collection of processes in which changes are characterized continuously through which material or energy flow occurs. While looking at the data retrieved from different repositories like Solar and Heliospheric Observatory (SOHO), we presume that due to variation of the physical and morphological properties of coronal mass ejections (CMEs) in the sun. There will be changes in theEarth's atmosphere corresponding to the solar cycle of CME. The CME parameters like intensity, halo, mass, acceleration, angular and linear speed from the SOHO data can be very much useful to Sun-Earth connection to drive important and dynamic state of the Earth system. We could infer here that CMEs might have aun-deciphered importance in the earth system processes (ESP).***

Keywords: Earth system processes (ESP); Sun;thermodynamic equilibrium (TE); Maximum entropy production (MEP); Irradiance; coronal mass ejection

1. Introduction

We propose that variation of solar diameter occurs albeit small due to coronal mass ejection (CME). Because of this amount irradance on the surface of the Earth will be affected which is supported by data from astronomical studies. This in turn will affect the free energy degrading processes within the Earth system and the entropy production of the Earth system processes (Stephens and O'brien, 1993; Kleidon, 2004, 2010). CMEs were first detected via coronagraph images obtained by NASA's OSO-7 spacecraft on December 14, 1971 (Gopalswamy, 2005). CME is a substantial discharge of plasma and associated magnetic field from the solar corona,usually follows solar flaresand are observed on solar prominence eruption(Gopalswamy et. al., 2006). Coronagraph imagery is used to observe this released plasma in the form of solar wind (Tandberg and Einar, 1995). Role of CME in other forms of solar activity isn't fully understood and established yet. From the extant literature it is believed that CME arise from most full of zip regions on the Sun's surface, such as groupings of sunspots associated with frequent flares. Frequency of CMEs on the Sun is about three per day and one per 5th day near solar maxima and near solar minima respectively (Gopalswamy, 2005). CMEs and solar flares are supposed to be overdue of magnetic reconnection which is sudden rearrangement of magnetic field lines when two oppositely directed magnetic fields are brought together and is called as magnetohydrodynamic theory. Reconnection releases energy stored in the original stressed magnetic fields. These magnetic field lines can become twisted in a helical structure, with a 'right-hand twist' or a 'left hand twist'. When the Sun's magnetic field lines turn more and more twisted, CMEs appear to be a faucetto release the magnetic energy being built up (Biskamp,2003). It has been evidenced by the helical structure of CMEsthat would otherwise renew itself continuously each solar cycle and eventually rip the Sun apart. Magnetic reconnection may happen on the Sun in solar arcades in a series of closely occurring loops of magnetic lines of force. These lines of force swiftly reconnect into a low arcade of loops, leaving a helix of magnetic field disparate to the rest of the arcade. So theabrupt release of energy during this progression causes the solar flare and ejects the CME (Su et. al., 2011). The helical magnetic field and the material that it contains may violently expand outwards forming a CME. This also explains why CMEs and solar flares typically erupt from what are known as the active regions on the Sun where magnetic fields are much stronger on average (Gopalswamy, 2004).

When the ejection is concentrating towards the Earth and reaches it as an interplanetary CME (ICME). Shock wave of traveling mass causes a geomagnetic storm that may disrupt Earth's magnetosphere, constricting it on the day side and extending the night-side magnetic tail. When the magnetosphere reconnects on the nightside, power is releasedin the order of terawatt scale, which is focused back toward Earth's upper atmosphere. Solar energetic particles can cause particularly strong aurorae in large regions around Earth's magnetic poles. These are also known as the Northern Lights (*aurora borealis*) in the northern hemisphere, and the Southern Lights (*aurora australis*) in the southern hemisphere. In addition coronal mass ejections, along with solar flares of other origin, can disrupt radio transmissions and cause damage to satellites and electrical transmission line facilities, resulting in potentially massive and long-lasting power outages (Manoharan, 2006). Free electrons in the ionospherecan be increased in the number by energetic protons released by a CME, especially in the high-latitude Polar Regions. The increase in free electrons canlead to Polar Cap Absorption (PCA) events via enhancing radio wave absorption, especially within the D-region of the ionosphere (Holman, 2006). Human beings at high altitudes, especially in airplanes or space stations, risk exposure to relatively intense solar particle events. The energy absorbed by astronauts is not reduced by a typical spacecraft shield design and, if any protection is provided, it would result from changes in the microscopic inhomogeneity of the energy absorption events. So the effect of CME on the Earth system processes yet to be deciphered can't be set aside as it impacts the Earth balance via change in geomagnetism and irradiation on the surface of the Earth. Thus CME is a kind of solar eruptions that might be impacting the changing of space weather as well Earths weather dynamics.

2. Materials and Methods

All the data that has been used in this paper has been downloaded from extant literature resources of NASA, ESA and other international observatories. SOHO, a project of international cooperation between ESA and NASA has been used to data regarding the coronal mass ejection and its parameters. The data availed was analysed in Microsoft excel.

3. Results and Discussion

The Solar and Heliospheric Observatory (SOHO) is a spacecraft that was launched on a Lockheed Martin Atlas II AS launch vehicle on December 2, 1995. It was built by a European industrial consortium led by Matra Marconi Space to study the Sun. Data of its operations from 1996 to 2017 was closely observed from the archives available on the databases. CME has been assigned with certain attributes which decides about the character of particular one. These attributes and parameters of CME are like intensity, halo, mass, acceleration, angular and linear speed. For the understanding variation in solar intensities due to the variant CMEs, three randomly chosen CMEs from specific time points in years 1997, 2007 and 2015 have been chosen to compare the intensity (**Figure 1**). Apart from on real time observation basis too there is variation in different parameters of CME. Real time imagery of the specific days can be observed for three days corresponding to years 1997, 2007 and 2015 in **Figure 2.**

On the basis of these parameters extremity of the CME is decided although there is no concrete definition of an extreme event. Loosely it is thought to be as an event on the tail of a distribution. The unique characteristics of an extreme event can in its origin or in its consequences. For Instance, CME with a great speed can be considered as an extreme event if such an incidence is rare. Among the thousands of CMEs observed by the Solar and Heliospheric Observatory (SOHO) from 1996 to 2017, only a couple have speeds exceeding 3000 km/s Therefore, one can consider a CME with speed exceeding 3000 km/s as an extreme event. To know about the speed of CME one has to consider the energy source of CMEs and how that energy is converted to CME kinetic energy. This is also supported by the previous studies that CMEs can only be powered by the magnetic energy in closed magnetic field regions on the Sun (Forbes, 2000). There are two types of closed field regions that are known to produce CMEs: sunspot regions (active regions) and quiescent filament regions (Gopalswamy et al., 2010). Potential energy in active regions can be computed is a considered as a potential measure of the maximum free energy available to power eruptions (Mackay et al. (1997). These studies have helped in understanding the conversion efficiency from the magnetic energy to CME kinetic energy which is a manifestation of extremity of CME.

Theparameters of CME like intensity, halo, mass, acceleration, angular and linear speed over the time period 20 years has been shown graphically to explain the CME over this time period. In this graphical interpretation of SOHO data for one or two specific points in an each year clearly shows that there is variation in the solar intensities over long-range time period (**Figure 3**). This can be manifested as a solar eruption is the form of flare, which is primarily identified with the sudden increase in electromagnetic emission from the Sun at various wavelengths. As we know that the primary source of energy to the Earth is radiant energy from the Sun. This radiant energy is measured and reported as the solar irradiance or total solar irradiance (TSI) when all of the radiation is measured. When measured as a function of wavelength it is the spectral irradiance. So we can say that more variation might be occurring when light of different wavelengths reaches different parts of the Earth's atmosphere. Many studies have shown substantial progress in the study of the Sun’s irradiation influence on climate, the ozone layer and other Earth system processes in recent years.

These phenomenons lead to geomagnetic storms which depend on the CME speed and its magnetic content. Each of these space weather events has a chain of effects on Earth’s magnetosphere, ionosphere, atmosphere, and even on the ground. In addition, SEPs pose radiation hazard to astronauts and adversely affect space technology in the near-Earth as well as interplanetary space. It must be noted that these events are responsible for a different types of electromagnetic emission when they propagate and interact with the solar surface.

The extreme space weather consequences thus depend on extreme CME properties. In the case of SEP events, one can think of very strong shocks, which ultimately result from very high CME speeds. It has been established that geomagnetic storms also depend on CME speeds as they arrive at Earth’s magnetosphere. They require intense southward magnetic field in the CME (Jason et.al., 2010). The shocks with high speed that arrive at Earth in less than a day are known as fast transit events (Gopalswamy et al. 2005). These shocks are considered to be extreme events because they can cause high levels of energetic storm particles (ESPs) at Earth and compress the magnetosphere observed as sudden impulse or sudden commencement (SC) of geomagnetic storms. Such shocks are also very strong near the Sun and are highly likely to accelerate SEPs to very high energies. The resulting SEP spectrum is expected to be hard leading to high-energy particles that affect the Earth’s ionosphere and atmosphere.

4. Acknowledgement

I thank Mr. Mohd Saleem Dar in helping me framing the ideas and acquiring the relevant data from observatories and the papers regarding the idea. I am thankful to SOHO, a project of international cooperation between ESA and NASA, where from I could download data to analyse and create the graphical representation of the CME variation.

5. Conclusion

Solar missions and the high quality data acquired from them over an extended period of time will provide new insights into role of CME like processes on the Earth system processes. It is being accepted now that CMEs constitute the most energetic phenomenon in the heliosphere. Although SOHO observatory data provides us a good notion about different properties of CME but we are still the infantile stage regarding the kinematic properties of CMEs and their magnetic. There is limited information available about the Magnetic properties of the CMEs formed near the sun. The Understanding of these CMEs near and their magnetic is crucial in developing long-term prediction of CME production. This understanding will also help in the prediction of potential impact on the Earth system process because the magnetic field orientation is a critical parameter. It has been seen that only the fast and wide CMEs (10% of all the CMEs) have space weather implications. Therefore, modelling efforts should concentrate on these CMEs for space weather applications. SOHO has provided a great deal of information on the initiation and 3D structure of CMEs. Yet, connecting disk signatures to coronagraphic signatures is still not easy due to the occulting disk employed by the coronagraphs. The STEREO mission is likely to alleviate some of these difficulties. STEREO has also the capability to provide information on the early-phase acceleration of CMEs. While the connection between SEP events and CMEs is fairly clear, there are many fast and wide CMEs that are not associated with SEPs. This needs a better characterization of the ambient medium such as density and magnetic field, which determine the local Alfven speed and hence shock formation. The effects of CME-induced turbulence and successive CMEs in the ambient medium have to be incorporated into the shock-acceleration theories. In fact CME is of interest from many dimensions and is highly relevant for a better understanding and prediction of the Earth system dynamics.

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Figure Legends:

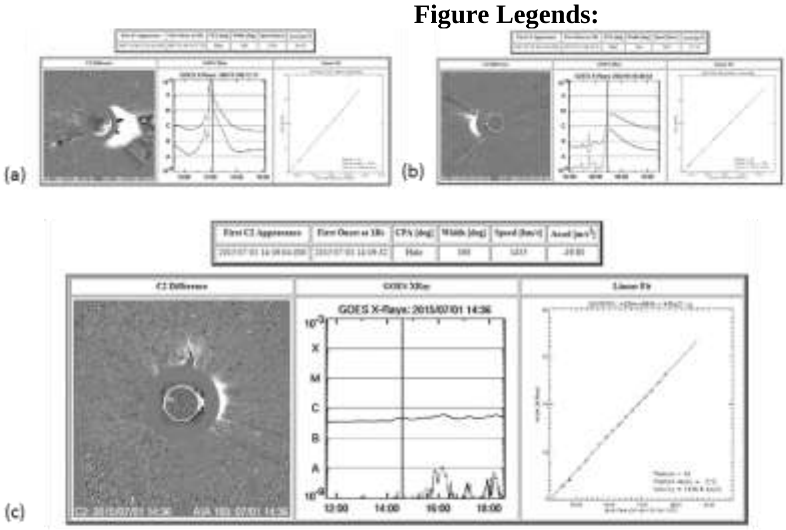

Figure 1: Images observed by SOHO, a project of international cooperation between ESA and NASA. They show CME parameters like intensity, halo, mass, acceleration, angular and linear speed. (a). (b) and (c) represent at three randomly chosen specific time points in years 1997, 2007 and 2015 to show variation in solar intensities.

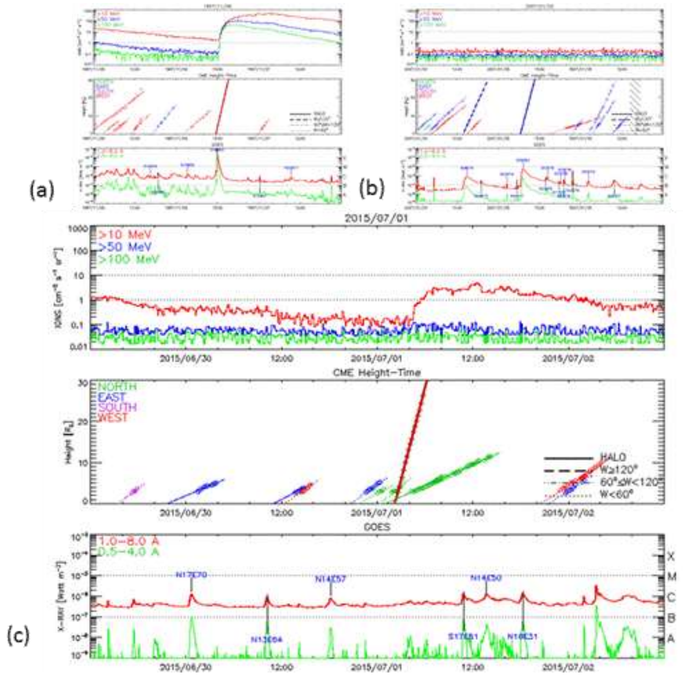

Figure 2: Images observed by SOHO, a project of international cooperation between ESA and NASA. Real time observation of the CME variation for three days corresponding to years 1997, 2007 and 2015 shown in (a), (b) and (c) respectively.

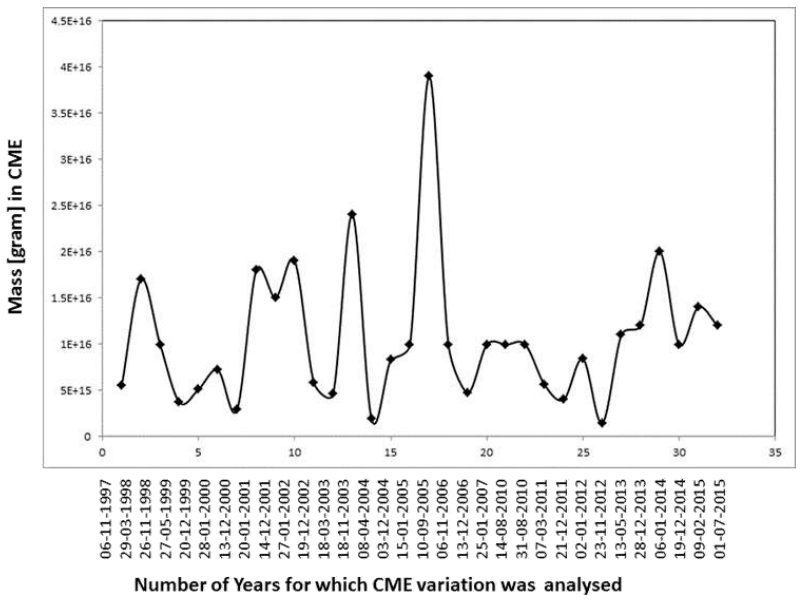

Figure 3: Graphic explanation of the CME over the time period 20 years by SOHO for one or two specific points in a each year clearly shows that there is variation in the solar intensities over long-range time period.