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Geomagnetic Storms and its Various Effects

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ABSTRACT

This paper throws a light on various effects of Geomagnetic Storms such as ionization, electromagnetic emission, ultraviolet radiation radio emission, etc. The accuracy of Global Positioning System (GPS) dimensions can be degraded by geomagnetic storms. It's affect also observed on earthquakes. Besides these effects, studies have shown the direct connection of geomagnetic storms with living organisms.

KEYWORDS: Geomagnetic, Storms, Ionosphere, Solar, Magnetosphere, Coronal Mass.

1. INTRODUCTION

A geomagnetic storm is a worldwide disturbance of the Earth's magnetic field associated with solar activity. It occurs in an interval of time when an intense and long-lasting interplanetary convection electric field leads through a substantial energization in the magnetosphere of the ionosphere system to an intensified ring current.

Extreme geomagnetic storms are considered as one of the major natural space event, which is dangerous for technology-dependent entities. Geomagnetic field disturbances can interrupt the operation of critical infrastructure depending on space-based assets.

The dominant interplanetary structures which triggered the most intense geomagnetic storms are magnetic clouds. Geomagnetic storms that occurred during a solar cycle are due to interaction among multiple magnetic clouds. (Cid et.al.2008). The direction of the interplanetary magnetic field vector and the solar wind speed are responsible for interplanetary disturbances to lead the occurrence of extreme of events.

A measure of this current the disturbance storm time (Dst) results of intense currents in the magnetosphere around the Earth. A measure of this current the Dst index is used to assess magnetic storms severity. Thus a Dst index below -50 nT is indication of moderate disturbance which an above it turns to intense (Gonzalez et. al. 1994) and super intense or extreme if Dst reaches to less than-250 nT from -100nT (Echer et.al.2008)

The intensity of geomagnetic storms can reach -685 nT (Cid et.al. 2013) to -2000nT (Siscoe 1979) Some storms of Dst -350nT occurred but no failure in infrastructure was reported.

There are currents produced in the magnetosphere known as the field-aligned currents and these connect to intense currents in the auroral ionosphere. These auroral currents are known as auroral electro jets also produce large magnetic disturbances. All of these currents and the magnetic deviations used to generate a planetary geomagnetic disturbance index called Kp. This index is one of the NOAA space weather scales, the geomagnetic storm or G-scale, that is used to describe space weather that can disrupt systems on the Earth.

An example from a large double storm of early November 2004 is shown. This storm produced auroras reported (among others) from Wisconsin, Verginia, and Europe.

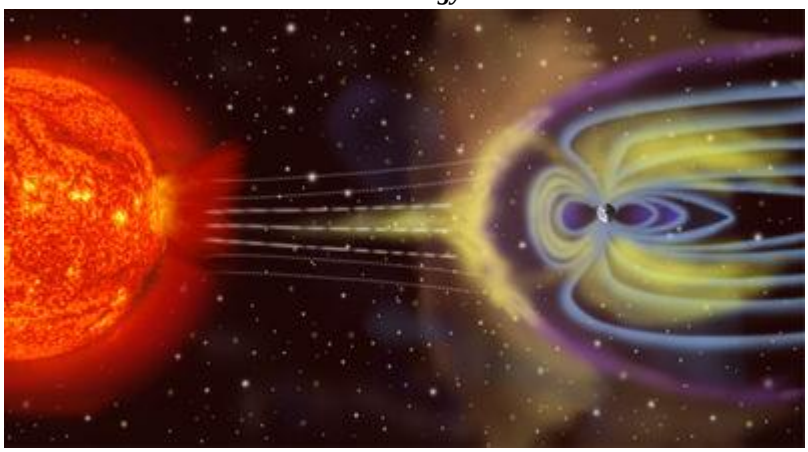

Fig.1 Solar Wind Particles Interacting with Earth's Magnetosphere

2. THEORY OF GEOMAGNETIC STROMS

A hydro magnetic theory explains the phenomenon of geomagnetic storms. A sudden increase in the intensity of the solar wind is the cause of a magnetic storm. The solar plasma impinging upon the geomagnetic field, which creates stresses. These stresses propagated to the earth as hydro magnetic waves account for the observed magnetic storms variations. A hydromagnetic wave generated by the impact of the solar plasma on the geomagnetic field commences the geomagnetic storms. The initial phase of the magnetic storm is due to the increased solar wind pressure. During this phase instability causes small plasma clouds to become imbedded in the magnetic field. They break up and diffuse into the magnetic field to form a belt of trapped particles (protons and electrons). The trapped protons induce stresses, due to centrifugal force, which accounts for the main phase of the geomagnetic storm. The recovery from the main phase is attributed to the relief of the stress on the geomagnetic field by the transfer of the energy of the trapped protons to neutral hydrogen by means of the ion-atom charge exchange process.

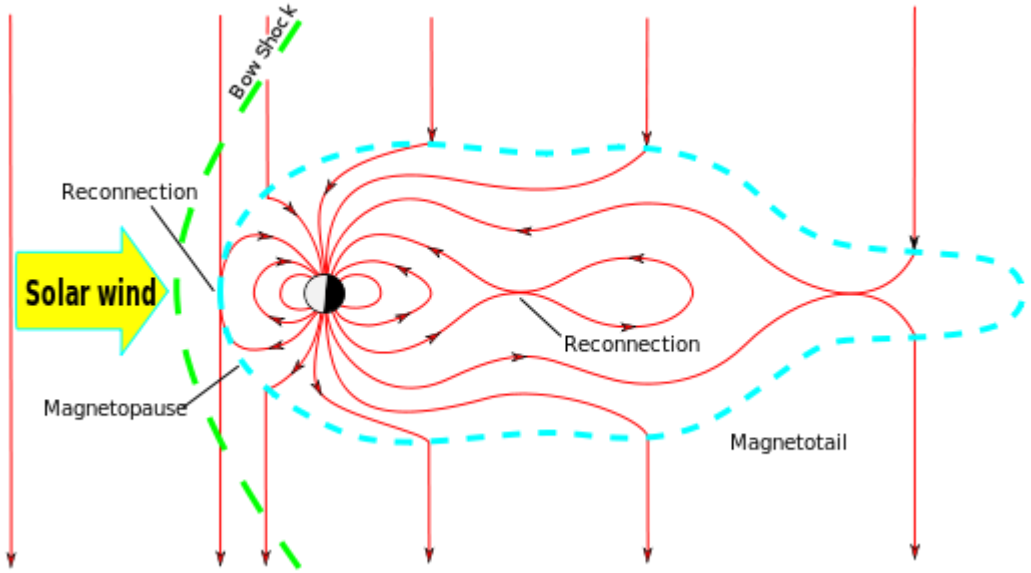

Fig.2 Magnetosphere in the Near-Earth Space Environment

3. CAUSES OF GEOMAGNETIC STROMS

Geomagnetic storms are induced by coronal mass ejections (CMEs) Coronal mass ejections are usually associated with flares but sometimes no flare is observed when they occur.

The Sun continuously emits a solar wind in all directions with very high speed and density. The wind blows radially away from the Sun and always contains a magnetic field which is highly variable in magnitude. When the magnetic field direction within the solar wind is directed opposite to the Earth's magnetic field then large geomagnetic storm can occur. The Sun emits bubbles or coronal mass ejections, which are faster, often more dense than normal and contain higher magnetic fields. When the sun is more active, coronal mass ejections occur more often and sunspots are more numerous during such time

High- speed solar wind stream (HSS) creates conditions favorable to geomagnetic storms. HSSs plow into the slower wind and create co-rotating interaction regions (CIRs).These regions are typically related to geomagnetic storms and less intense than CMEs storms, which deposit more energy in Earth's magnetosphere over a longer interval.
The main causes of the geomagnetic storm can be explained as follows.
Solar Flare: A spark of intensity found over the Sun's exterior, which is interpreted as a huge energy released up to (6*10 to the power 25) joules of energy is called as a solar flare. It is the most magnificent event which may cause a geomagnetic storm.

With the explosion of the solar flare which is present in the radiance of the Sun that discharges a huge quantity of energy in the form of outward-streaming elements.

Coronal Holes: Coronal holes are the element of the Sun coronas and these holes change their shape regularly. The Sun is not only even but also exposed by "holes". Particles break away from with relatively easier. These particles after coming from corona holes arrived at higher velocities in their outward expansion in contrast to regular solar wind elements and produce speedy streams. These speedy streams when combining with the slower speed solar wind released from areas which are without holes and release the same sloping of the IMF (Interplanetary Magnetic Field). Coronal holes continue for much 27 solar (equatorial) revolution and as a consequence, produce recurring geomagnetic storms.

The largest storms are associated with (CMEs) where a billion tons or so of plasma from the Sun with its embedded magnetic field, arrives at Earth but in the period of the most intense storms, they take few hours to arrive.

3.1 Types of Geomagnetic Storms

There are two major categories of geomagnetic storms.

- Recurrent Storms
- Non-recurrent Storms

Recurrent Storms

Recurrent storms occur when the Earth is exposed to the high-pressure magnetic fields which are generated at the juncture of low and high-speed solar wind streams in the vicinity of the Sun. These streams are seen in declining cycle of the solar cycle. They occur every 27 days corresponding to the Sun's rotation period.

Non-Recurrent Storms

The main source of non-recurrent storms is interplanetary disturbances due to coronal mass ejections (CMEs). These storms are seen when the solar phase is at its peak. They typically involve an encounter with both the interplanetary shock wave and the CME that drives it.

Space Weather Alert

Space weather API provides access to near real-time data from the space weather services section of the Australian Bureau of Meteorology.

3.2 Phases of Geomagnetic Storms

A geomagnetic storm is divided into three parts.

- Initial phase
- Main phase
- Recovery phase

Initial Phase

In this phase of a geomagnetic storm, the intensity increased by twenty to fifty nT (in tens 0f minutes). It is also known as Storm Sudden Commencement (SSC). In most of the storms, there is no unexpected increase in disturbance storm time. This phase is connected by means of the density of the magnetosphere, which results in enhanced local strength. The period of this phase can be up to 2-8 hours.

Main Phase

In this phase geomagnetic storm is characterized in terms of disturbance storm time, usually less than -50nT. The lower bound of values during the course of the storm is said to be in the range of -50 nT and -600nT. Its period may vary up to 24 hours.

Recovery Phase

This phase results from reconciliation between the lower and bound and normal range of storm time. Its range can be from few hours to seven days.

3.3 Effect of Geomagnetic Storms

It effects on human activities occur during major geomagnetic storms.
The behavior of relativistic electrons gets affected by geomagnetic storms. It can increase or decrease the fluxes of relativistic electrons in the radiation belts.

During storms, the currents in the ionosphere as well as the energetic particles that participate in the upper atmosphere, causing extra drag on satellites in low earth orbit. The regional heating also creates strong horizontal variations in the ionosphere density that can change the path of radio signals and create errors in the positioning information's provided by GPS.

While the storms create magnificent aurora, they can also disrupt navigation systems such as the Global Navigation Satellite Systems (GNSS) and create a harmful geomagnetic induced current in the power grid and pipelines.

It refers to that impact which is likely to be happening when a geomagnetic storm occurs.

Induced Currents: Irregularities in power system voltage can be possible. On some protection device, false alarms may be elicited.

Spacecraft: A large drag on low Earth-orbit satellites and compass reading problems.

Routing: Irregular satellite routing troubles, including loss-of-lock there may be enlarged in range error.

Radio: Distortion in high-frequency radio may occur.

Earthquakes: Many strong earthquakes come just because of solar flares and CMEs (main causes of geomagnetic storms) which influences the Earth's tectonic plates and release a high energy.

Biological Effects: Studies shows that there is a direct relation between the Sun's planetary storms and living organisms. The solar flares i.e. charged particles from Sun to Earth surface are responsible for human disturbances.

Psychological Effects: It has been documented that geomagnetic activity is associated with more than 35% increase in depression [Kay (1994)]. Even more unsettlingly, [kuleshova et.al. (2001)] noticed almost a double increase in hospitalization case due to mental health and cardiovascular problems during geomagnetic activity. Zakharov and Tyrnov (2001) found the origin of the psychological effects arise from effects emanating from pineal gland which disturbs the natural circadian rhythm of the body as well as melatonin bio-synthesis.It is a known fact that abnormal melatonin levels are associated with mood fluctuations. Similar findings have been documented in Hirshleifer and Shumway (2003), Wright and Bower (1992), Loewenstein (2000) and Johnson and Tversky (1983).

People attribute to geomagnetic activity for their decision which is made during the period.Here is shown a model of Individual Investor Financial decisions based on the findings

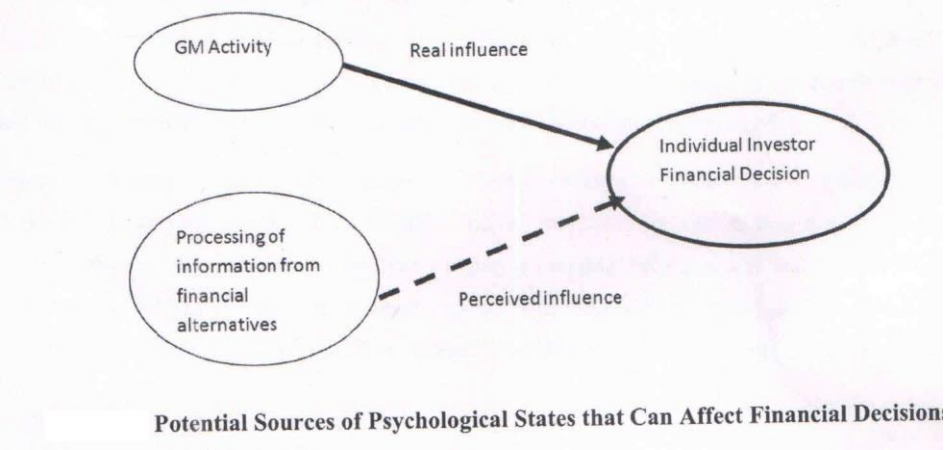

Fig.3 Potential Sources of Psychological States that can Affect Financial Decision

The dotted lines indicate the little presence of psychological effects that emanate from information available to individual investors as regards the various financial alternatives available to them. Hence it is called the perceived influence and the real influence on psychological states is coming from geomagnetic activities, which is therefore indicated with solid line [Priya Jindal and Shilpa Bahl (2017)].

Effects on Capital Market: The geomagnetic storm indirectly influences the overall market returns. The demand for riskless assets is quite high due to a negative future prediction which ultimately causes the prices of riskier assets to fall or there will steadily rise in the price i.e. there is a pessimistic fundamental link between geomagnetic activities and returns from the capital market.

The geomagnetic storms have a deep outcome on investor's behavior, human behavior, judgments and decision about risk. The experimental research has shown the straight link between investor's mood, their decision making, and their psychology.

Space Weather Alert: Space weather API provides access to near real-time data from the space weather services section of the Australian Bureau of Meteorology. Space weather predictions are usually obtained by the database – calibrated. Models (Shrivastava 2005, Kataoka.2013, Yermolaev et.al.2013) Rodrigue z et.al. (2009). Gonzalez et.al (2007) and Echer et.al. (2008).

Conclusion: The influence of latitude in geomagnetic storms is well known as geomagnetic disturbances are usually larger at high latitudes due to the effect of aurora electro jet.

The solar flares when accompanying CMEs becomes more intense, thus causing even stronger interplanetary and magnetosphere effects. This will have important implications for the Sun-Earth system.

Intense solar flares release very high energy particles that can cause radiation poisoning to human similar to low energy radiation from nuclear blasts.

The geomagnetic activity in Earth's atmosphere has significant effects on technology, power grid and relative temperature on Earth.

It is suggested to gather the data and research about the effects and implications of the geomagnetic storms on the archive of different atmospheric, astronomical and another scientific journal to fully extract the essential factors so that the implications can be fully drawn.

4. ACKNOWLEDGMENT

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Gupta C. Rashmi received the M.Phil. Degree in Physics from University of Roorkee (Indian Institute of Technology Roorkee) in 1988.She has served as a Lecturer of physics in LNCT Bhopal and National Institute of Technology Bhopal, India.

