Sudan University of Science and Technology

College of Graduate Studies

Geomagnetic Storms Sudden Commencement (SSC) Type and Implications on the Ground at Low Latitudes

العواصف الجيومغنطيسية من النوع فجائية صدمة البداية وأثارها المترتبة علي الارض في المناطق المنخفضة

A thesis submitted as to fulfill partial requirements of Master degree of Science (M.Sc.) in Physics.

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Dedication

This thesis dedicated to my beloved mother,

My wife Alice and all my kids

To all Lecturers Doctors whom supported in this task.

And to all my friends and colleagues, I dedicate this work.

Acknowledgements

I first acknowledge support of my wife Alice Daniel, without her encouragement and patience, I would not reach these.

Second, I am deeply indebted to my supervisor, all lecturer doctors for their fully assistances

Colleagues who have help me for the several issues. I'm sure that I have left a few people out, I apologize to them.

Finally, I would like to thank the Post Graduate College in general and College of Science in particular, for the great efforts we have been given.

Abstract

In this research, we reviewed physics of some events in solar terrestrial environment include phenomenon in the region of space between the surface of the Sun and the upper atmosphere (magnetic field) of the Earth. The matter in this region is in plasma state. The methodology adopted here is to investigate the occurrence of storm sudden commencement SSC type of storms in some time span from (2007 to 2008) via the space weather index, Disturbance in the storm time Dst index, and hence to check occurrence of pulsation continuous Pc5 at low latitudes ground stations in particular, the global mode, then eventually checking whether blackout occurred or not in local region here in Sudan. From the data being analyzed a one event of blackout was found to occur associating Global mode Pc 5 pulsations occurring as a result of SSC storm. This result show that SSC type of storms has a potential sever impact in the low latitudes regions.

المستخلص

استعرضنا في هذا البحث، فيزياء بعض الأحداث في البيئة الشمسية الأرضية وتشمل الظواهر في منطقة الفضاء بين سطح الشمس والجو العلوي (المجال المغناطيسي) للأرض. المادة في هذه المنطقة في حالة البلازما. في هذا البحث تم تبني طريقة في التحقق من حدوث العواصف الجيومغناطيسية من النوع فجائية صدمة البداية عن طريق مؤشر طقس الفضاء للتيار الحلقي حول الأرض (Dst) وذلك في الفترة الزمنية (2007–2008)، ومن ثم التحقق من حدوث النبضات الجيومغناطيسية المستمرة، خصوصا عالميّة الإنتشار، ومن ثم وأخيرا، التحقق من حدوث إظلام تام في شبكة الكهرباء في منطقة محلِّية من مناطق خطوط العرض المنخفظة، في السودان. أظهرت النتائج حدوث إظلام تام متزامنا مع حدوث نبضات جيومغناطيسية عالمِّية الإنتشار ظهرت بآليَّة حدوث عاصفة جيومغناطيسية من النوع فجائية صدمة البداية. هذه النتيجة توضِّح أن العواصف الجيومغناطيسية من النوع فجائية صدمة البداية لها آثار حادة متوقعة في مناطق خطوط العرض المنخفضة.

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List of Abbreviations

CME	Coronal Mass Ejections.
DSCOVR	Deep Space Climate Observatory.
Dst	Disturbance Storms Time.
GI	Geomagnetically Induce Currents.
GPS	Global Positioning System.
GNSS	Global Navigation Satellite system.
HSS	High Speed Solar wind Storms.
Kp	Planetary Geomagnetic Disturbance Index.
LASCO	Large Angle and Spectrometric Corona graph.
MHD	Magnetic hydrodynamics.
Pc5	Pulsations’ Continuous.
Pd	Dynamic Pressure.
SI	Sudden Impulse.

CHAPTER ONE

INTRODUCTION

1.1.General Introduction

Geomagnetically induced current (GIC), in long distance conductive ground infrastructures such as: pipe lines, communication cables, and high voltage transmission system, are harmful space weather that affects society. In particular, its affect extends to modern power networks. It is well known that the primary cause of(GICs) is interaction between solar wind and geomagnetic field which induces geoelectric field on the Earth's surface, producing GIC in transmission lines, large GIC are usually observed at the high latitude location due to the large magnitude and high rates of change of magnetic field disturbance caused by intensification of ionospheric electro-jets in association with sub-storm, thus GIC had been considered as particular high latitude problem for long time. However there is some reports showing that GIC can disrupt the power networks at the lower latitudes in extreme events for example (Gaunt & Coetzee, 2007)reported that some of transformer failures were detected in South Africa after Halloween storm 2003.

In order to transport a significant amount of the electricity over a greater distance the trend has been to build long transmission lines which exposed to larger induced voltage driving large GIC (Zhang, et al., 2015). This makes power networks at the lower latitudes more vulnerable to GIC attacks. To examine the GIC effect observations and /or modeling works have been conducted in many mid-lower latitude countries for instance China, Japan, Australia, Newzeland, Brazil and South Africa (Johnsen, March 17 2015).It well established that the main phase of geomagnetic storm which associated with ring current intensifications causes large GIC, and hence risk factor for power system failure at middle and low latitudes (Zhang, et al., 2015), increas. However some disruptions of the power networks at lower latitudes caused by geomagnetic sudden impulse SI or storm sudden commencement SSC, which is defined as a specific kind of SI that is followed by a storm. Zhang, et al.; 2015,have reported that the magnetosphere shock associated with SSC had even cause some power network failure in America for example an SSC occurred on 15 July 2000 storm triggered simultaneous tripping of the capacitor banks at two substations in Tennessee Valley Authority power grid.

1.2. Statement of the Research Problem

It is well known that space weather in general has an impact in our technological systems both in the ground and in situ, e.g. geomagnetic storms cause some disruptions of the technological systems(power networks, pipelines, electrical power, communication, … etc.) at different locations in the globe. However, recently, space weather impact has been found to take place even at locations in the lower latitudes in the globe, and usually caused by geomagnetic sudden impulse SI or storm sudden commencement SSC. Therefore evaluation of the impact of SSC storms at lower latitudes become of importance so as to mitigate the resulting effects that might be caused by the power failure or disruption in these lower latitudes regions. Hence, in this dissertation an investigation of the expected impact of a SSC storms in the case of the location of Sudan shall be carried out.

1.3. Objectives of the Research Project

Objectives of this research:

1- Investigate the occurrence of SSC type of storms in some time span: 2007 to 2008.
2- Specify occurrence of pulsations continuous (Pc5) at low- latitude ground, pulsations associated with onset time of SSC type of storms and determine whether global mode occurred or not.
3- Investigate the occurrence of blackouts in Sudan associated with the onset of SSC storms.

1.4. Outline of the Research Project

This dissertation is arranged in four chapters, chapter one which is general introduction including objectives, chapter two discuss geomagnetic storms GIC, storms sudden commencement SSC trough the studying of the Sun and it's properties, the Sun spots and solar cycle, solar spots and solar cycle, solar magnetic field, corona holes, corona mass ejection CME, the solar wind, radiation belts and ring current, storms dangerous to us, solar storms can be dangerous to technologies, space weather, the hazards of geomagnetic storms, solar flares cause earthquakes, earth core generate magnetic field, earthquakes associated with variations in geomagnetic field and how do the solar flares affect weather, people and the earth.

Chapter three discussed research methodology and the physical processes of underlying the geomagnetic effects on solar wind dynamic pressure pd variations. Chapter four contains results, observations and summary.

CHAPTER TWO

THEORETICAL BACKGROUND

2-1.**Introduction**

But have been A geomagnetic storm is a major disturbance of Earth's magnetosphere that occurs when there is a very efficient exchange of energy from the solar wind into the space environment surrounding Earth. These storms result from variations in the solar wind that produces major changes in the currents, plasmas, and fields in Earth’s magnetosphere. The solar wind conditions that are effective for creating geomagnetic storms are sustained (for several to many hours) periods of high-speed solar wind, and most importantly, a southward directed solar wind magnetic field (opposite the direction of Earth’s field) at the dayside of the magnetosphere. This condition is effective for transferring energy from the solar wind into Earth’s magnetosphere

observed, for some of the most intense storms, to arrive in as short as 18 hours. Another solar wind disturbance that creates conditions favorable to geomagnetic storms is a high-speed solar wind stream HSS. HSSs plow into the slower solar wind in front and create co-rotating interaction regions, or CIRs. These regions are often related to geomagnetic storms that while less intense than storms, the largest storms that result from these conditions are associated with solar coronal mass ejections where a billion tons or so of plasma from the sun, with its embedded magnetic field, arrives at Earth. CMEs typically take several days to arrive at the earth; often can deposit more energy in Earth’s magnetosphere over a longer interval.

Storms also result in intense currents in the magnetosphere, changes in the radiation belts, and changes in the ionosphere, including heating the ionosphere and upper atmosphere region called the thermosphere. In space, a ring of westward current around Earth produces magnetic disturbances on the ground. A measure of this current, the disturbance storm time Dst index, has been used historically to characterize the size of a geomagnetic storm. In addition, there are currents produced in the magnetosphere that follow the magnetic field, called field-aligned currents, and these connect to intense currents in the auroral ionosphere. These auroral currents, called the auroral electro jets, also produce large magnetic disturbances. Together, all of these currents, and the magnetic deviations they produce on the ground, are used to generate a planetary (Odenwald, 2001)geomagnetic disturbance index called Kp. This index is the basis for one of the three NOAA Space Weather Scales, the Geomagnetic Storm, or G-Scale, that is used to describe space weather that can disrupt systems on Earth.

During storms, the currents in the ionosphere, as well as the energetic particles that precipitate into the ionosphere add energy in the form of heat that can increase the density and distribution of density in the upper atmosphere, causing extra drag on satellites in low-earth orbit. The local heating also creates strong horizontal variations in the ionospheric density that can modify the path of radio signals and create errors in the positioning information provided by GPS. While the storms create beautiful aurora, they also can disrupt navigation systems such as the Global Navigation Satellite System GNSS and create harmful geomagnetic induced currents GICs in the power grid and pipeline.

2.2 Storm Sudden Commencement

A very clear jump in the solar wind speed as well as the interplanetary magnetic field strength was seen by the ACE satellite which is located upstream in the solar wind, see the figure (2.1) below. This is typical the signature of an interplanetary shock and in this case the passage of the front of a coronal mass ejection (CME). The particular shock according to the Solar Influences Data Center in Belgium, associated with an earlier than predicted arrival of a CME that left the Sun on March 15.

Now, from a geomagnetic point of view, what happens when Earth is hit by such an interplanetary shock? The geomagnetic signature is very clear and global, and termed a sudden impulse SI, or depending on what happens afterwards a Storm Sudden Commencement SSC.

Roughly speaking, the SI is the superposition of two effects, seen as a very short lived oscillation and a positive step in the magnetic field. The former is the signature of the reorganization of the magnetosphere as the shock front propagates along the magnetopause towards the magneto tail, and the current system established to resist the change. Depending on local time and latitude, the oscillation will start with a negative or positive excursion. The latter is caused by the magnetopause current (Chapman-Ferraro current) increasing and being pushed closer to Earth.

A very good review article about such events has been written by Araki (1994).

So, what will happen now? As mentioned above, we may also call the event a Storms sudden commencements will we get a geomagnetic storm? We have certainly been hit by an interplanetary shock associated with a CME…

What determines if we get a storm or not, is basically the Interplanetary Magnetic Field direction, if its z-component (the one which is parallel to Earth’s magnetic axis, seen as the red curve in the top figure) becomes negative for extended periods of time during the next 24 hours, we have a geoeffective situation, then we will certainly get storm conditions. So far, during moment of our investigation, it has been negative most of the time, and conditions are indeed active on a global scale. How it develops, we just have to wait and see (Johnsen, March 17 2015)

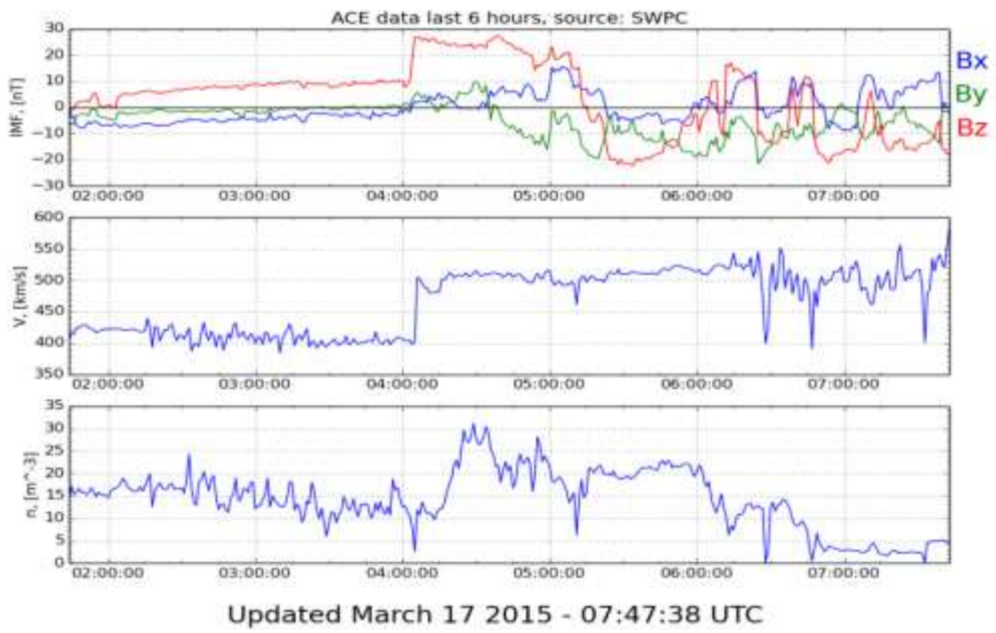


Figure 2.1: 6 hours of solar wind data from ACE (Johnsen, March 17 2015)

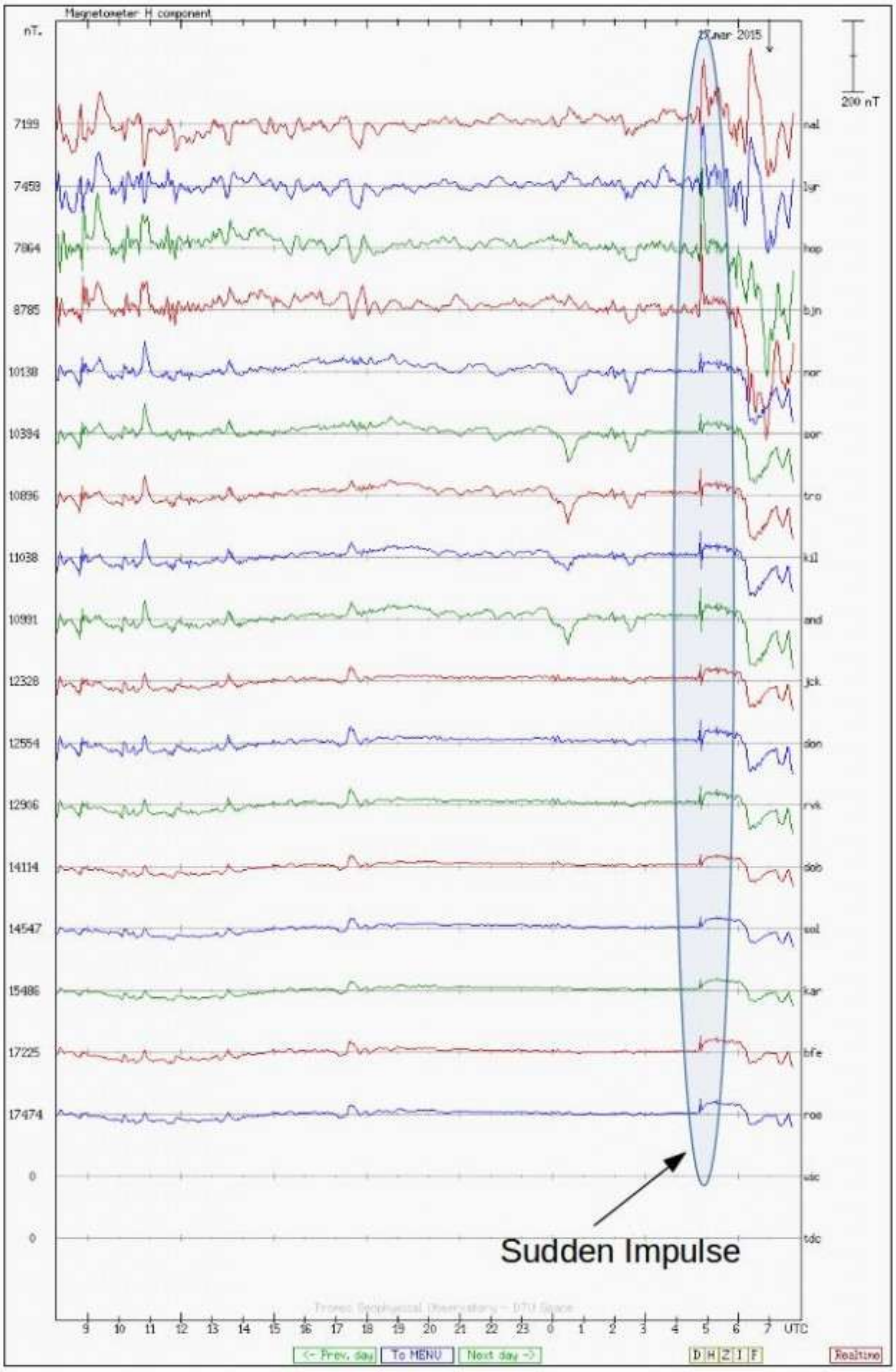


Figure 2.2: Sudden impulse observed (Johnsen, March 17 2015)

2.3. The Sun as the source of (SSC):

The Sun is a medium sized star, consisting largely of hydrogen with significant fraction of helium. To a first approximation, it can be regarded a plasma in gravitational and magneto hydrostatic equilibrium. It is heated from within by a fusion reaction. Energy is conducted outward from the core through the conduction region. At about two thirds of radius, convection becomes dominant process. Its magnetohydrodynamics behavior is discussed by Priest. Observation evidence for wide variety of phenomena and the properties of the sun can be found in some books (Odenwald, 2001). Some major properties of the Sun are listed in Table below.

Table:2.1 Properties of the sun

Mass	$1.99\text{x}10^{30}$kg
Radius	$6.91\text{x}10^{5}$km
Core temperature	$1.4\text{x}10^{7}$k
Surface temperature	5750k
Core density	$1.4\text{x}10^{5}$kgm^{-3}
Luminosity	$3.86\text{x}10^{26}$w
Lost rate of matter	10^{9}kgs^{-1}
Equatorial rotation period	27.6 days

The visible outer (Walker, 2005) heated by acoustic shock dissipation. Beyond the chromospheres is the Sun. The visible surface of the Sun is called the photosphere. Its position defines solar radius. Visually, it has a change granular structure as a consequence of convection processes going to blow it May be disturbed by violent phenomena occurring in active regions.

These are consequences of MHD processes, driven by the energy source in the core. Immediately above the photosphere in a thin 20000 km region called chromospheres. Originally observed during solar eclipses, it can be seen on the sun limb on the totality as having a pink color. It characterized by rapid temperature raise through its thickness and a great deal structure. It is not in thermal equilibrium with the interior and is probably atmosphere. If the disc of the Sun is screened, a pale region of bright can be seen extending several solar radii. This is the solar corona. It can be regarded as the lower region of the Sun's atmosphere. It is also at a high temperature, greater than the 10^6K. Beyond the corona the atmosphere flows out wards as the solar wind. A variety of active visual features can be observed on the surface of the photosphere and in the corona and photosphere. These are summarized in table (2). Much of the terminology has been derived from the empirical observation. As a consequence, the same phenomena may have been given different names according to how it was observed. The table is intended to provide a vocabulary for referring to processes on the Sun's surface (Walker, 2005)

2.4. Sun spots and solar cycle

The granular surface of the photosphere is a regularly disturbed by the appearance of Sun spots. There are dark features on the surface. Visually, they consist of dark central umbra, often surrounded by the paler penumbra. The radius of the umbra ranges between 2500 km and 20000 km, with atypical value of 10000km.

Table 2.2 Phenomena at the surface of the Sun

Phenomenon	Description
Active region	Extended area of the photosphere and corona in which spots, flares, plages, prominences and filaments occur
Bipolar region	Region in photosphere that shows bipolar magnetic field. Includes sunspots but also active regions without sunspots
Coronal hole	Region of open magnetic field lines and low plasma density. Source of high-speed plasma streams.
Coronal mass ejection	A cloud of corona material is ejected from the sun.
Faculae	Bright irregular patches near sunspots on the limb.
Filament	Dark elongated feature near reversal of

	magnetic field. Seen has a bright prominence on the limb.
Limb	The visible edge of the Sun
Penumbra	Paler region surrounding the umbra of Sunspots
Plage	Bright emission in active region
Polar plumes	Short high –latitude streamers bordering polar region. Correspond to more or less permanent coronal holes.
Prominence	Feature consisting of relatively cool plasma, projecting up into the corona.
Phenomenon	Description
Solar flare	An explosive release of energy in active region. Electromagnetic radiation and particles are emitted.
Solar oscillations	Line-of-sight oscillations of photosphere, with periods in the 5 min range.
Sunspots	Dark feature on surface of photosphere. Occur in pairs or group coinciding bipolar region.
Umbra	Dark center of Sunspots.

Its area is about 20%of the total of the spot similar dark feature with small radii and missing the penumbras are known as pores. The darker color of the spots is because they are at the much lower temperature than their surroundings. Individual spots may have lifetime ranging between less than hours to several months. The Sunspot under varies with an average period of 11.1 yr. This is known as the solar cycle during the solar cycle, the median latitude at which they appear moves from about 25^0 to the equator over the solar cycle, while the zone occupied at any one time extends over about 15^0 of latitude. Sunspots tend to occur in the pairs. The surface magnetic field at lower latitudes is largely confined to the neighborhood of the, Helioseismic oscillation

The sub solar region exhibits coherent fluid dynamics oscillations with frequencies that can be measured with the accuracies up to one part in 10^5. These are reviewed by Libbrechtand Woodard

2.5. The Solar magnetic field

The Sun's magnetic field is complicated. Knowledge of its nature comes from observation of photosphere and, corona using the variety of the techniques. Observations show that it is highly localized in active regions on a range of spatial and temporal scales. At one time, the main field was thought to be roughly dipolar in nature, with large amount of superposed fine structure, driven by dynamo processes in interior, and reversing the direction every 11yr. This is the case. Later observations show that field reversals at opposite poles may take place as much as 1yr apart, it is more likely there is more than one current system in the interior, each being driven by the dynamo processes arising from the rotation. In the steady state system, the associated magnetic field, frozen into the plasma, would be confined to the region inside the photosphere and unobservable from outside. However, the photosphere represents the outer boundary of the convection region. This is very far from the steady-state system. Instead, local dynamic processes cause eruptions on the surface of the Sun. This eject plasma and frozen-in flux tubes into corona and eject plasma is observed as a variety of filaments, prominences, flares, and other phenomena. It is a magnetic field associated with the phenomena that is observed magnetic field of the Sun.

The large scale magnetic field of the sun is thought to be driven by dynamo processes in the plasma, the most favored model being that of Babcock. This is the descriptive kinetic model. There has been much subsequent work of the details of the dynamics but some aspects are still controversial. In out line, an initially poloidal interior field, frozen into plasma, is distorted by latitude-dependent rate of rotation of the plasma. Near the equatorial, plane this differential rotation drags the field into toroidal orientation. There is tendency for afield to be twisted into concentrated flux ropes. Dynamic processes occurring at the surface carry this flux ropes into corona. There is the large-scale weaker field near the poles

The strongest field occurred the number of Sun spots. Field magnitudes in the umbra range from about 0.15 T in the smallest pots to about 0.4 T in the largest. Visual observations of the bright structures in the corona as well as measurements of the field suggest local bipolar structure. In the simplest case, the poles coincide with sunspots pair. More complex cases have magnetic structure coinciding with sunspots group, with apart of corresponding to one polarity and the other part of to the positive polarity .Because of the differential rotation with latitude, the more equatorial spots of the group of pair lead, the magnetic polarity between northern and southern hemispheres and between successive solar cycles. There is, thus a 22yr sunspot cycle if magnetic polarity taken into the account. There is a large-scale weaker field near the poles. This also reverses every 11yr at the maximum of the solar cycle. There is evidence that the fields at opposite poles are not part of the single system since there reversals may be separated by up to a year (Walker, 2005).

2.6. Coronal holes

Coronal holes, in contrast, are extended regions with weaker magnetic field, the field lines are connected to the interplanetary field and the field thus has a local unipolar structure. Generally then near the Sun, the coronal magnetic field has a complicated structure. In it there are fundamentally two kinds of regions. These are characterized by the close and open field lines. Both ends of closed field lines are anchored in the photosphere; however only one end of an open field lines medium. The most prominent sources of closed field lines are sunspots; the most prominent sources of the open field lines are coronal holes (Odenwald, 2001)

2.7. CORONAL MASS EJECTIONS

Coronal Mass Ejections CMEs are large expulsions of plasma and magnetic field from the Sun’s corona. They can eject billions of tons of coronal material and carry an embedded magnetic field (frozen in flux) that is stronger than the background solar wind interplanetary magnetic field IMF strength. CMEs travel outward from the Sun at speeds ranging from slower than 250 kilometers per second (km/s) to as fast as near 3000 km/s. The fastest Earth-directed CMEs can reach our planet in as little as 15-18 hours. Slower CMEs can take several days to arrive. They expand in size as they propagate away from the Sun and larger CMEs can reach a size comprising nearly a quarter of the space between Earth and the Sun by the time it reaches our planet.

The more explosive CMEs generally begin when highly twisted magnetic field structures (flux ropes) contained in the Sun's lower corona become too stressed and realign into a less tense configuration – a process called magnetic reconnection. This can result in the sudden release of electromagnetic energy in the form of a solar flare; which typically accompanies the explosive acceleration of plasma away from the Sun – the CME. These types of CMEs usually take place from areas of the Sun with localized fields of strong and stressed magnetic flux; such as active regions associated with sunspot groups. CMEs can also occur from locations where relatively cool and denser plasma is trapped and suspended by magnetic flux extending up to the inner corona - filaments and prominences. When these flux ropes reconfigure, the denser filament or prominence can collapse back to the solar surface and be quietly reabsorbed, or a CME may result. CMEs travelling faster than the background solar wind speed can generate a shock wave. These shock waves can accelerate charged particles ahead of them – causing increased radiation storm potential or intensity.

Important CME parameters used in analysis are size, speed, and direction. These properties are inferred from orbital satellites' coronagraph imagery by SWPC forecasters to determine any Earth-impact likelihood. The NASA Solar and Heliospheric Observatory SOHO, carries a coronagraph – known as the Large Angle and Spectrometric Coronagraph LASCO. This instrument has two ranges for optical imaging of the Sun's corona: C2 (covers distance range of 1.5 to 6 solar radii) and C3 (range of 3 to 32 solar radii). The LASCO instrument is currently the primary means used by forecasters to analyze and categorize CMEs; however another coronagraph is on the NASA STEREO-A spacecraft as an additional source.

Imminent CME arrival is first observed by the Deep Space Climate Observatory DSCOVR satellite, located at the L1 orbital area. Sudden increases in density, total interplanetary magnetic field IMF strength, and solar wind speed at the DSCOVR spacecraft indicate arrival of the CME-associated interplanetary shock ahead of the magnetic cloud. This can often provide 15 to 60 minutes advanced warning of shock arrival at Earth – and any possible sudden impulse or sudden storm commencement; as registered by Earth-based magnetometers.

Important aspects of an arriving CME and its likelihood for causing more intense geomagnetic storming include the strength and direction of the IMF beginning with shock arrival, followed by arrival and passage of the plasma cloud and frozen-in-flux magnetic field. More intense levels of geomagnetic storming are favored when the CME enhanced IMF becomes more pronounced and prolonged in a south-directed orientation. Some CMEs show predominantly one direction of the magnetic field during its passage, while most exhibit changing field directions as the CME passes over Earth. Generally, CMEs that impact Earth's magnetosphere will at some point have an IMF orientation that favors generation of geomagnetic storming. Geomagnetic storms are classified during a five-level NOAA Space Weather Scale. SWPC forecasters discuss analysis and geomagnetic storm potential of CMEs in the forecast discussion and predict levels of geomagnetic storming in the 3-day forecast (Kamide & Abraham C, 2007).

2.8. The solar wind

The solar wind consists of plasma streaming outward from the Sun. It can be regarded as the outer part of the sun's atmosphere. Its outer part boundary is thought to determine shock called the heliopause, in the outer regions of the solar system, forming the interface between solar plasma and interstellar medium. The region within the termination shock is known as the heliosphere, provides an extended account of many of the properties of the heliosphere. It's precedes modern area on near-continuous solar wind observations by the satellites well upstream of the Earth and space probes in distant solar system but provides a good overview of the development of the theoretical understanding up to 1971. More recently Barnes has provided as outlines of current understanding of solar wind acceleration.

The solar wind is variable and gusty. It carries with it a frozen-in magnetic field originating from the Sun. this field variable in magnitude and direction. It has been extensively observed by in situ satellites which provide information on the plasma composition, velocity, temperature, and density, and three components of the magnetic field. A favored position for such satellites in an orbit about the point between Earth and Sun where the gravitational force is reduced so that the period of the satellite is the same as that of the Earth. Some properties of the solar wind are summarized in the table (2.3) all of these can be found in the book of Basic Space Plasma Physics (Walker, 2005).

Table 2.3 Properties of solar wind plasma (Odenwald, 2001).

Property	Value
Total plasma number density	$3x10^{6}$-$2x10^{7}m^{-3}$
Proton fraction	0.95of positive ions by number
Particle fraction	<0.05 of positive ions by number
Radial velocity	300-700kms^{-1}
Dynamic pressure,1/2 ρv^{2}	$2x10^{-10}$-$8x10^{-9}$pa
Proton temperature	$3x10^{4}$-$2x10^{5}$k
Electron temperature	10^{5}K
Magnetic field	2-20 nT

2.9 Radiation belts and ring current

Have seen how dawn-dusk and co rotation electric field combine a region within which cold plasma is essentially trapped so that it effectively co rotates with the earth. Hot plasma is subject to the same fields but also experiences other drifts due to the gradient curvature of the magnetic field which modify the trapping region. Nevertheless, the net effect is that there is the energy- dependent trapping boundary within which energetic particles can be stably trapped to form the radiation belts. Within these belts, injection and loss processes are, in balance. The energies of protons in the inner region extended to hundreds of MeV. The bulk 0f the particles have energies of the order of tens of kev.

At times of sub storms, particle from the magneto tail are injected into the radiation belt region. They lead to a large increase in plasma pressure and a resulting ring current which substantially modifies the geomagnetic field on the ground (Walker, 2005).

2.9.Storms Dangerous to us

Activity on the sun affects Earth's magnetic field. It can cause geomagnetic storms, the same events that create the beautiful aurora, or northern and southern lights. Are these storms dangerous?

In an active part of the sun's 11-year cycle of activity, those using telescopes equipped with special solar filters to peer at the sun – or photograph it – can see dark sunspots dotting the sun's surface. Space observatories will detect short-lived but brilliant and powerful solar flares – intense bursts of radiation and our solar system's largest explosive events – lasting minutes to hours on the sun's surface. Occasional, powerful coronal mass ejections, or CMEs – giant bubbles of gas and magnetic fields from the sun, containing up to a billion tons of charged particles that can travel up to several million miles per hour – are released into the interplanetary medium. This solar material streams out through space, and sometimes strikes Earth. Is this dangerous? Should we be worried? (Odenwald, 2001)

2.10. Solar storms aren't dangerous to humans on Earth's surface.

These storms are awesome to contemplate, but they cannot harm our human bodies as long as we remain on the surface of Earth, where we're protected by Earth's blanket of atmosphere. Remember, there's every reason to believe that storms on the sun have been happening for billions of years, since the sun and Earth came to be. If that's so, then all life on Earth evolved under their influence.

What is the danger of a solar storm in space? Very high-energy particles, such as those carried by CMEs, can cause radiation poisoning to humans and other mammals. They would be dangerous to unshielded astronauts, say, astronauts traveling to the moon. Large doses could be fatal.

Still, solar storms – and their effects – are no problem for us on Earth's surface. Earth's atmosphere and magnetosphere protect our human bodies from the effects of solar flares. (Odenwald, 2001)

2.11. Solar storms can be dangerous to our *technologies*:

When a coronal mass ejection, or CME, strikes Earth’s atmosphere, it causes a temporary disturbance of the Earth’s magnetic field. The storm on the sun causes a type of storm on the Earth, known as a geomagnetic storm.

The most powerful solar storms send coronal mass ejections CMEs, containing charged particles, into space. If Earth happens to be in the path of a CME, the charged particles can slam into our atmosphere, disrupt satellites in orbit and even cause them to fail, and bathe high-flying airplanes with radiation. They can disrupt telecommunications and navigation systems. They have the potential to affect power grids, and have been known to black out entire cities, even entire regions.

People talking about power failures from solar storms always point back to March 13, 1989, 31 years ago. A CME caused a power failure in Québec, as well as across parts of the northeastern U.S. In this event, the electrical supply was cut off to over 6 million people for nine hours.

But it’s possible for solar storms to be even more powerful than the one that caused the 1989 Québec and U.S. northeast blackout. The largest known solar flare took place on August 28, 1859. It was observed and recorded by Richard C. Carrington, and so it’s sometimes called the Carrington Event, or sometimes the 1859 Solar Super storm. The accompanying coronal mass ejection (CME) traveled to Earth in only 17 hours, rather than the usual three or four days. The largest recorded geomagnetic storm occurred. Aurora, or northern lights, were seen in many parts of the world. Telegraph systems throughout Europe and North America failed.

What would happen if such a powerful solar storm occurred today? And is such a powerful solar storm likely to occur again in our lifetimes? No one knows the answers to these questions with certainty pipelines.

But scientists have become increasingly aware of the possibility, especially since 2008, when Sten Odenwald and James Green published an article in the magazine Scientific American about the Carrington Event and possible consequences if such a powerful storm on the sun occurred today.

Scientists are asking more questions about solar storms and their consequences. For example, in 2012, scientists publishing in the journal space Weather suggested that a 2001 power failure in New Zealand was caused by a solar storm. That result, if true, is particularly important because New Zealand is not at a high latitude (as Québec is, for example). It's at middle latitude, the same latitude as much of the United States.

Scientists – for example at the Space Weather Prediction Center – continually monitor the sun, both from space and from Earth's surface. When a solar storm with the potential to affect Earth takes place, they see it. After all, in order to affect us on Earth, the solar storm would have to happen on the side of the sun facing Earth. After such an event, it usually takes several days for the coronal mass ejection, or CME, to reach Earth. When a big CME is on its way, it is possible for satellites to shut their systems off briefly, and thereby remain safe. Likewise, with advance warning, Earth-based power grids can be reconfigured to provide extra grounding, and so on.

Are we in danger from a particularly huge solar storm, perhaps on the scale of the Carrington Event? Some believe we may be. That is why governments and scientists are beginning to pay more attention to this issue, with an eye to creating systems and procedures to help withstand such powerful effects from the sun (Kamide & Abraham C, 2007).

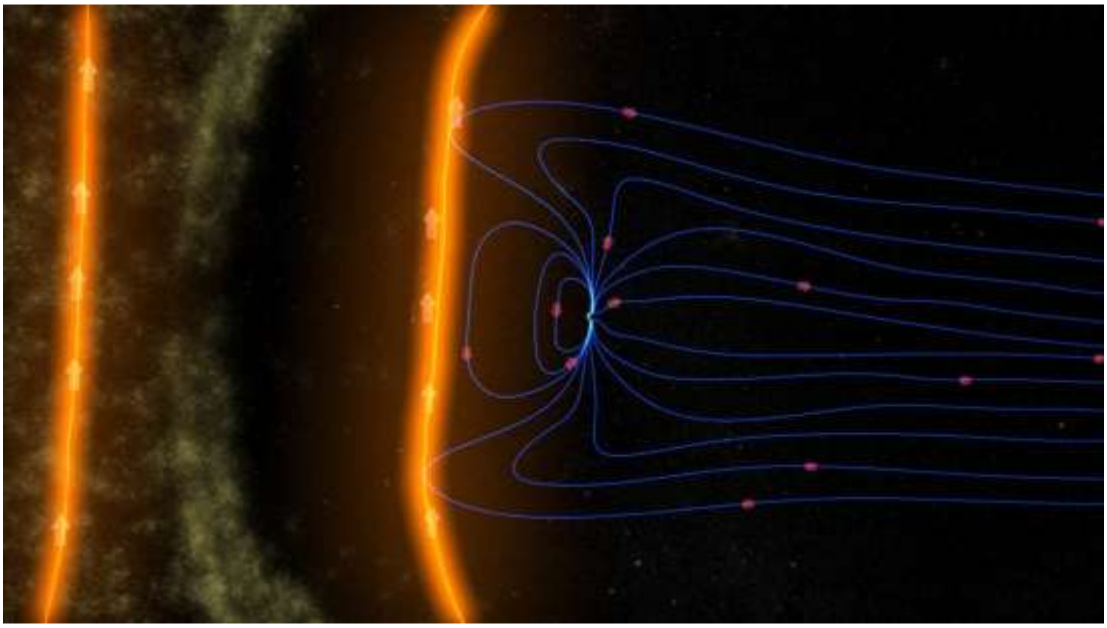


Figure (2.3) Earth’s magnetic field shielding our planet from solar particles (Odenwald, 2001)

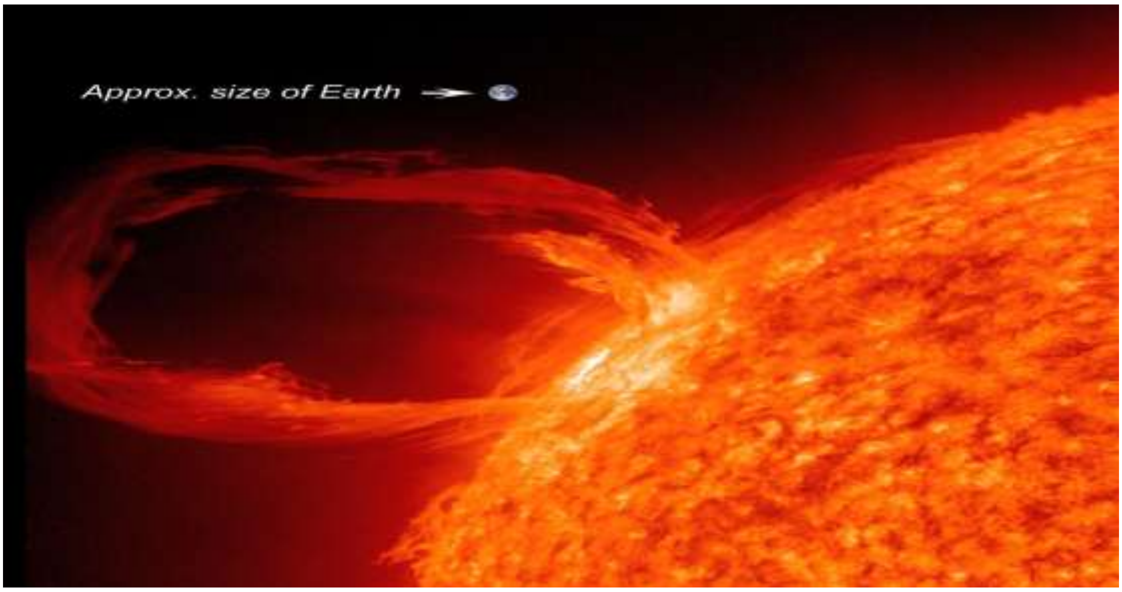


Figure (2.4) A solar prominence is vast and awesome in size in contrast to our little Earth. But the Earth is so far from the sun that these prominences pose no danger (Odenwald, 2001)

2-13. Space Weather

2.13.1. What impact do solar flares have on human activities?

Solar flares produce high energy particles and radiation that are dangerous to living organisms. However, at the surface of the Earth we are well protected from the effects of solar flares and other solar activity by the Earth's magnetic field and atmosphere. The most dangerous emissions from flares are energetic charged particles (primarily high-energy protons) and electromagnetic radiation (primarily x-rays).

The x-rays from flares are stopped by our atmosphere well above the Earth's surface. They do disturb the Earth's ionosphere, however, which in turn disturbs some radio communications. Along with energetic ultraviolet radiation, they heat the Earth’s outer atmosphere, causing it to expand. This increases the drag on Earth-orbiting satellites, reducing their lifetime in orbit. Also, both intense radio emission from flares and these changes in the atmosphere can degrade the precision of Global Positioning System GPS measurements (Walker, 2005).

The energetic particles produced at the Sun in flares seldom reach the Earth. When they do, the Earth's magnetic field prevents almost all of them from reaching the Earth's surface. The small number of very high energy particles that does reach the surface does not significantly increase the level of radiation that we experience every day.

The most serious effects on human activity occur during major geomagnetic storms. It is now understood that the major 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. Like flares, CMEs are more frequent during the active phase of the Sun's approximately 11 year cycle. The last maximum in solar activity, the maximum of the current solar cycle, was in April, 2014.

Coronal mass ejections are more likely to have a significant effect on our activities than flares because they carry more material into a larger volume of interplanetary space, increasing the likelihood that they will interact with the Earth. While a flare alone produces high-energy particles near the Sun, some of which escape into interplanetary space, a CME drives a shock wave which can continuously produce energetic particles as it propagates through interplanetary space. When a CME reaches the Earth, its impact disturbs the Earth's magnetosphere, setting off a geomagnetic storm. A CME typically takes 3 to 5 days to reach the Earth after it leaves the Sun. Observing the ejection of CMEs from the Sun provides an early warning of geomagnetic storms. Only recently, with SOHO, has it been possible to continuously observe the emission of CMEs from the Sun and determine if they are aimed at the Earth.

One serious problem that can occur during a geomagnetic storm is damage to Earth-orbiting satellites, especially those in high, geosynchronous orbits. Communications satellites are generally in these high orbits. Either the satellite becomes highly charged during the storm and a component is damaged by the high current that discharges into the satellite, or a component is damaged by high-energy particles that penetrate the satellite. We are not able to predict when and where a satellite in a high orbit may be damaged during a geomagnetic storm.

Astronauts on the Space Station are not in immediate danger because of the relatively low orbit of this manned mission. They do have to be concerned about cumulative exposure during space walks. The energetic particles from a flare or CME would be dangerous to an astronaut on a mission to the Moon or Mars, however.

Another major problem that has occurred during geomagnetic storms has been the temporary loss of electrical power over a large region. The best known case of this occurred in 1989 in Quebec. High currents in the magnetosphere induce high currents in power lines, blowing out electric transformers and power stations. This is most likely to happen at high latitudes, where the induced currents are greatest, and in regions having long power lines and where the ground is poorly conducting.

These are the most serious problems that have occurred as a result of short-term solar activity and the resulting geomagnetic storms. A positive aspect of geomagnetic storms, from an aesthetic point of view, is that the Earth's auroras are enhanced (Kamide & Abraham C, 2007).

Figure (2-5): Short term solar activity (Odenwald, 2001)

The damage to satellites and power grids can be very expensive and disruptive. Fortunately, this kind of damage is not frequent. Geomagnetic storms are more disruptive now than in the past because of our greater dependence on technical systems that can be affected by electric currents and energetic particles high in the Earth's magnetosphere.

Could a solar flare or CME be large enough to cause a nation-wide or planet-wide cataclysm? It is, of course, impossible to give a definitive answer to this question, but no such event is known to have occurred in the past and there is no evidence that the Sun could initiate such an event (Odenwald, 2001).

2.13.2. What are the hazards of magnetic storms?

Our technology-based infrastructure can be adversely affected by rapid magnetic-field variations. This is especially true during "magnetic storms."

Because the ionosphere is heated and distorted during storms, long-range radio communication that relies on sub-ionospheric reflection can be difficult or impossible and global-positioning system GPS communications can be degraded.

- Ionospheric expansion can increase satellite drag and make their orbits difficult to control.
- During magnetic storms, satellite electronics can be damaged through the build up and discharge of static-electric charges. Astronauts and high-altitude pilots can be subjected to increased levels of radiation.
- Even though rapid magnetic-field variations are generated by currents in space, very real effects can result down here on the Earth’s surface. That includes voltage surges in power grids that cause blackout (Worid, March/16/2020)

2.13.3. Do solar flares or magnetic storms (space weather) cause earthquakes?

Solar flares and magnetic storms belong to a set of phenomena known collectively as "space weather". Technological systems and the activities of modern civilization can be affected by changing space-weather conditions. However, it has never been demonstrated that there is a causal relationship between space weather and earthquakes. (Odenwald, 2001)

2.13.4. Why measure the magnetic field at the Earth's surface? Wouldn't satellites be better suited for space-weather studies?

Satellites and ground-based magnetometers are both important for making measurements of the Earth’s magnetic field. They are not redundant but are instead complementary: satellites provide good geographical coverage for data collection. Ground-based magnetometers are much less expensive and much easier to install than satellites

2-13.5. What is a magnetic storm?

A magnetic storm is a period of rapid magnetic field variation. It can last from hours to days. Magnetic storms have two basic causes: The Sun sometimes emits a strong surge of solar wind called a coronal mass ejection. This gust of solar wind disturbs the outer part of the Earth's magnetic field, which undergoes a complex oscillation (Walker, 2005).

2.13.6. Does the Earth's magnetic field affect human health?

The Earth's magnetic field does not directly affect human health. Humans evolved to live on this planet. High-altitude pilots and astronauts can experience higher levels of radiation during magnetic storms, but the hazard is due to the radiation, not the magnetic field itself. Geomagnetism can also impact the electrically-based technology (Odenwald, 2001)

2.13.7. Are we about to have a magnetic reversal?

Almost certainly not, since the invention of the magnetometer in the 1830s, the average intensity of the magnetic field at the Earth's surface has decreased by about ten percent. We know from pale magnetic records that the intensity of the magnetic field decreases by as much as ninety percent at the Earth's surface during a reversal (Kamide & Abraham C, 2007).

2.13.8. **How does the Earth's core generate a magnetic field?**

The Earth's outer core is in a state of turbulent convection as the result of radioactive heating and chemical differentiation. This sets up a process that is a bit like a naturally occurring electrical generator, where the convective kinetic energy is converted to electrical and magnetic energy, basically, the motion of the electrically. (Odenwald, 2001)

2-13.9.**Do any mass extinction correlate with magnetic reversals?**

No. There is no evidence of a correlation between mass extinctions and magnetic pole reversals. Earth’s magnetic field and its atmosphere protect us from solar radiation. It’s not clear whether a weak magnetic field during a polarity transition would allow enough solar radiation to reach the Earth's surface that it would cause extinctions

2.13.10. Are earthquakes associated with variations in the geomagnetic field?

Electromagnetic variations have been observed after earthquakes, but despite decades of work, there is no convincing evidence of electromagnetic precursors to earthquakes. It is worth acknowledging that geophysicists would actually love to demonstrate the reality of such precursors, especially if they could be used for reliably predicting (Worid, March/16/2020).

2.13.11. How Do Solar Flares Affect People and the Earth?

Solar activity that is intense enough to send solar flares or Coronal Mass Ejections CMEs into the Earth's atmosphere will affect the Earth's electromagnetic energy field EEF. The CMEs will also affect each person's EEF. The depth of the effect on each person can vary. However, first one must examine how CMEs affect the Earth's EEF. (Odenwald, 2001)

2.13.12. What are the Human Impacts of Solar Storms and Space Weather?

In satellite losses, can be traced to space weather damage. The last major space storm cause dam electrical blackout in Quebec. You have already been affected by solar storms and do not know it. Solar flares have cost the airline industry millions of dollars. (Odenwald, 2001)

2-13.13 Do geomagnetic storms affect Humans as well as Telecommunications?

It has long been established that magnetic storms not only affect the performance of equipment, upset radio communications, blackout radars, and disrupt radio navigation systems but also endanger living organisms. They change the blood flow, especially in capillaries, affect blood pressure, and boost adrenalin.

2.13.14. What Impact Do Solar Flares Have on Human Activities?

Coronal mass ejections are more likely to have a significant effect on our activities than flares because they carry more material into a larger volume of interplanetary space, increasing the likelihood that they will interact with the Earth. While a flare alone produces high-energy particles near the Sun, some of which escape into interplanetary space, a CME drives a shock wave which can continuously produce energetic particles as it propagates through interplanetary space.

2.13.15. How Does Solar Activity Affect Weather and Earth?

Weather on Earth can also be affected. Recently, NOAA scientists finally concluded that four factors determined global temperatures: carbon dioxide levels, volcanic eruptions, Pacific El Niño pattern, and the Sun's activity**.** There is also historical evidence that long-term periods of global cold, rainfall, drought, and other weather shifts relate to solar cycle activity (Odenwald, 2001)

CHAPTER THREE

DATA AND METHODOLOGY

Dst data were collected from the World Data Center of Kyoto University (Nose, et al., 2015), and a time span of Dst data from 2007 -2008 was being investigated to check the onset of SSC type of storms; furthermore, solar wind data including speed and pressure were obtained from OMNI website interface (Papitashvili, 2020) to get plots so as to investigate their influence on the onset of the SSC type of storms; and furthermore, ground data were selected from ground based stations; CMD, HER and SMA, and these data were filtered and the fast Fourier transforms FFT from such a time series data were calculated and the dynamic plots for Pc 5 pulsations were obtained.SSC occurred on Oct, 2007, Nov, 2007, December, 2007, and Jan, 2008, figures: Figure (3-1.a), Figure (3-2.a), Figure (3-3.a), and Figure (3-4.a) show this; a time span of three days before onset of SSC and three days after were taken for data of solar wind speed and pressure so as to investigated sources of expected occurrence of Pc 5 pulsations on the ground. Figures: Figure (3-1.b), Figure (3-2.b), Figure (3-3.b), and Figure (3-4.b) show this.

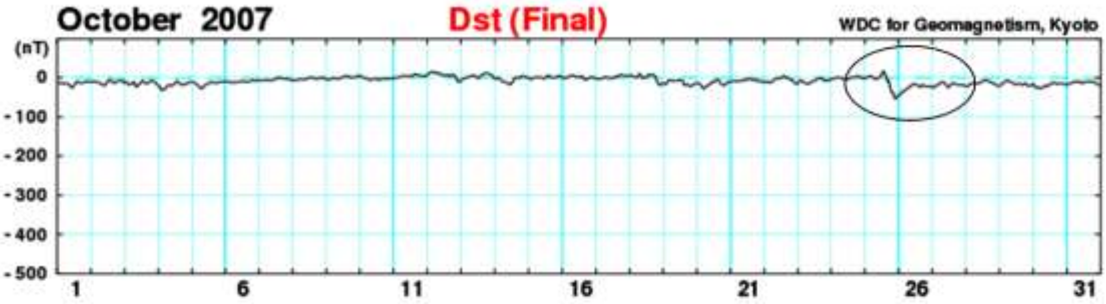


Figure (3-1.a): Show (SSC) occurred, represented by oval diagram; when Dst check applied; October/26/ 2007.

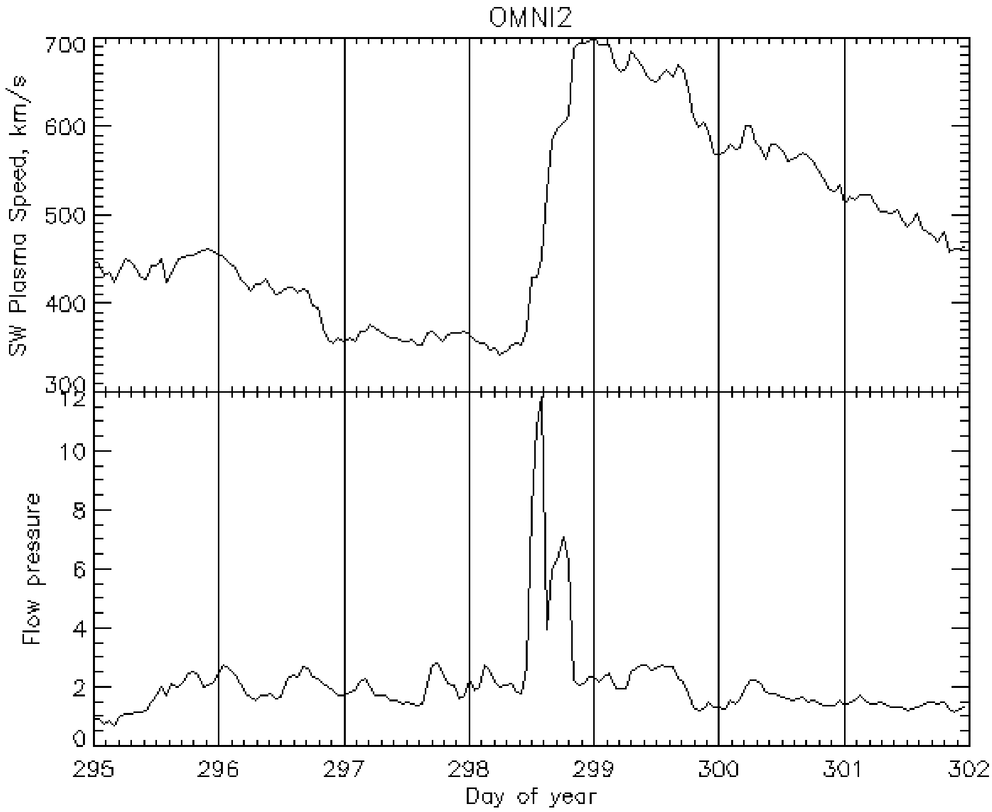


Figure (3-1.b): Show the relation between plasma's speed and the flow of pressure. After checked solar wind, it observed that SW started almost 450Km/s it blowing smoothly, reaches about 700Km/s; as a result, the flow of pressure increased gradually and reaches the peak in 26th, according to (Papitashvili, 2020).

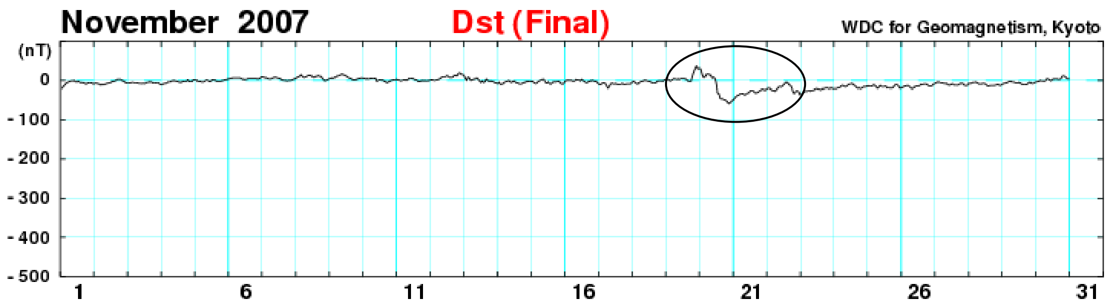


Figure (3-2.a): Show SSC occurred, represented by oval diagram; when Dst check applied; November/19/ 2007.

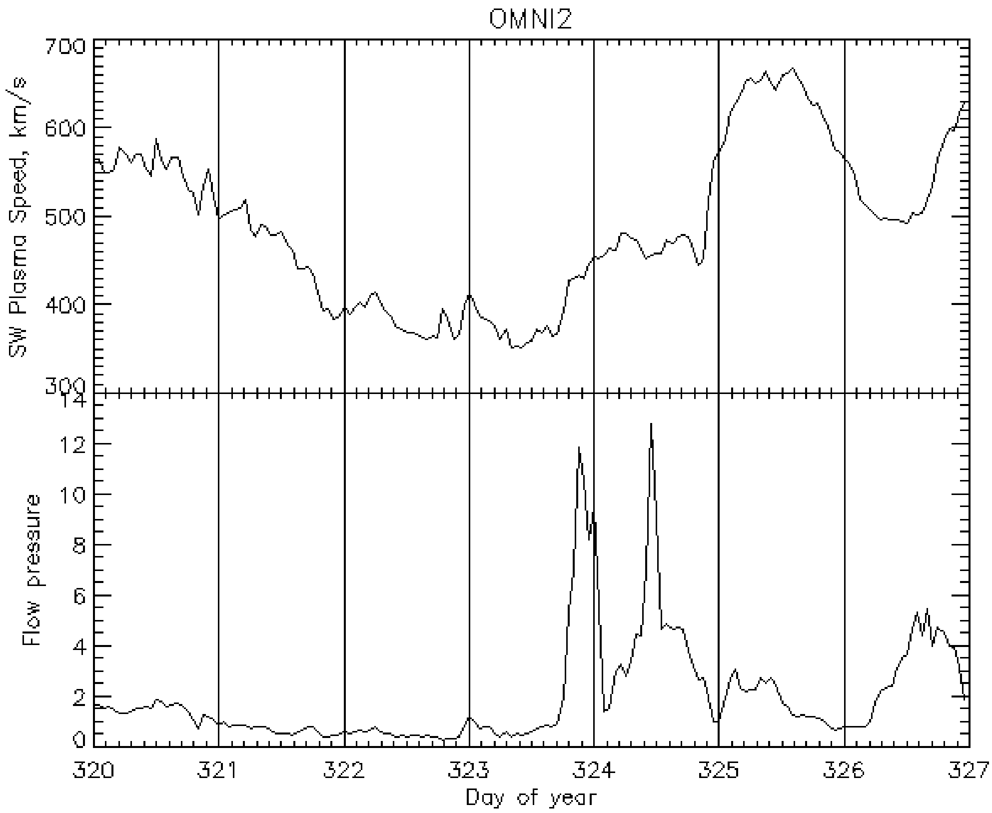


Figure (3-2.b): Show the relation between plasma's speed and the flow of pressure. After checked solar wind, it observed that SW started almost 550Km/s it blowing smoothly, reaches about 650Km/s; as a result, the flow of pressure started from abut2 increased gradually and reaches the peaks abut 10 and 11 nP_a as result there is SSC occurred in date19th. (Papitashvili, 2020)

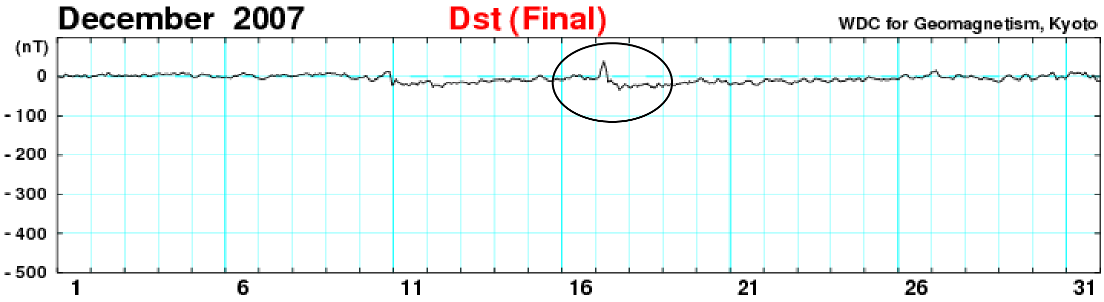


Figure (3-3.a): Show SSC occurred, represented by oval diagram; when Dst check applied; December/20/ 2007

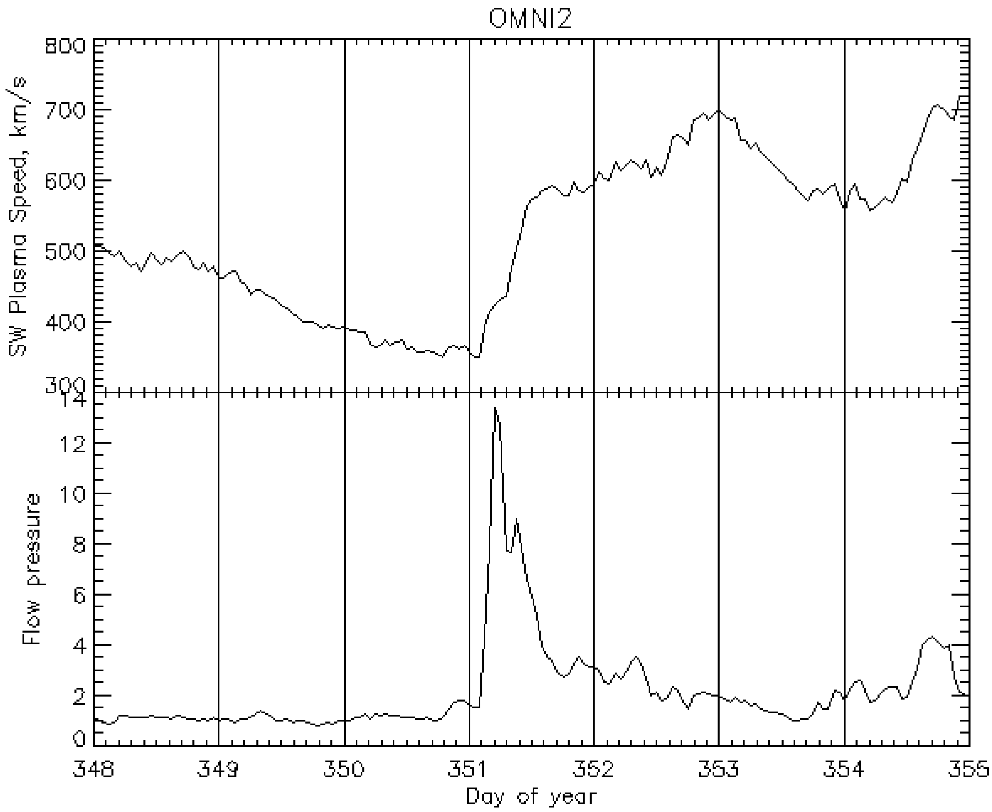


Figure: (3-3.b): Show the relation between plasma's speed and the flow of pressure. After checked solar wind, it observed that SW started almost 500Km/s it blowing smoothly, reaches about 700Km/s; as a result, the flow of pressure started from abut1 nP_a, increased gradually and reaches the peaks about 13 nP_a as result there is SSC occurred in date20th. (Papitashvili, 2020)

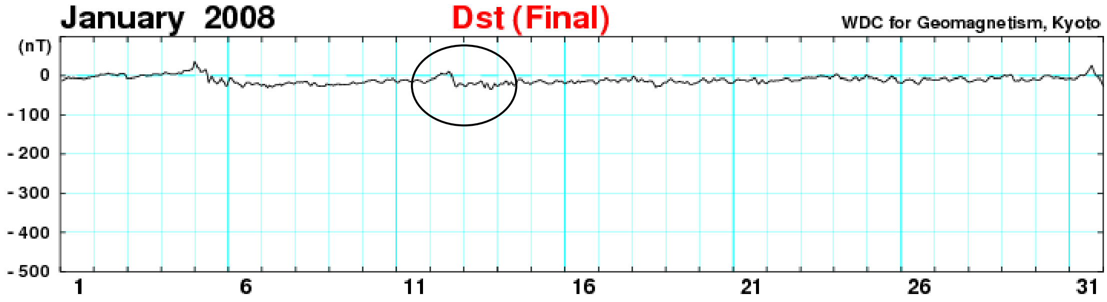


Figure (3-4.a): Show SSC occurred, represented by oval diagram; when Dst check applied; January/13/ 2008

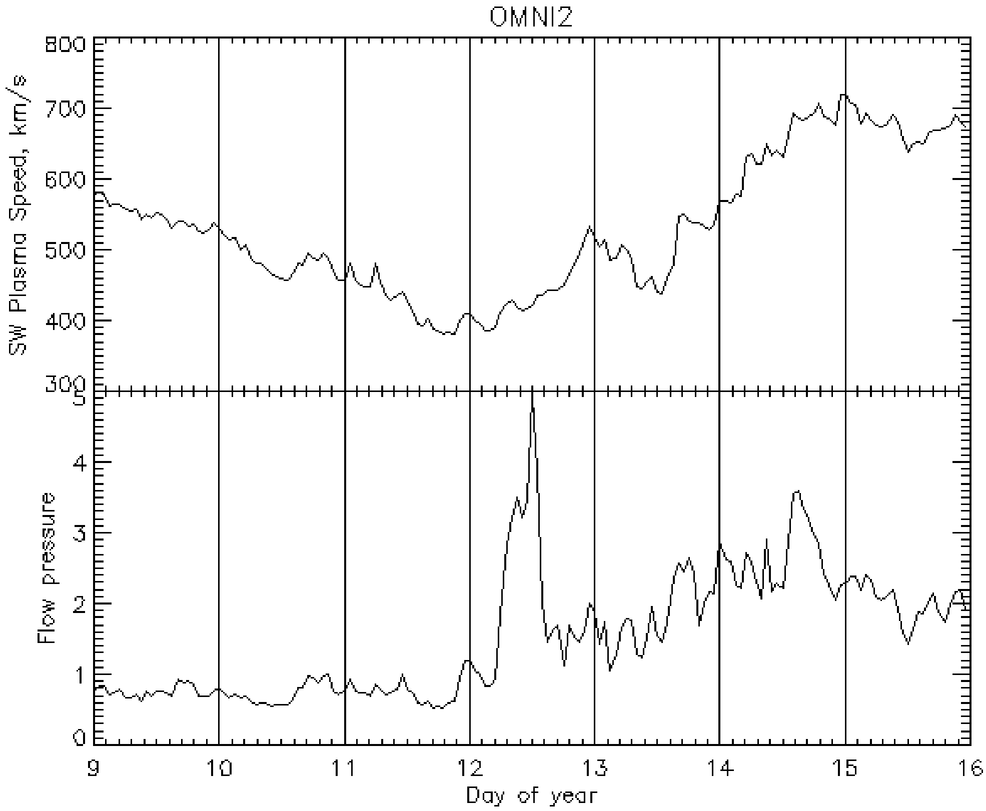


Figure (3-4.b): Show the relation between plasma's speed and the flow of pressure. After checked solar wind, it observed that SW started almost 580Km/s it blowing roughly decrease and suddenly started raise in zigzag, reaches about 680Km/s; as a result, the flow of pressure increased gradually and reaches the peak in 5 nP_a day site. Increasing flow of the pressure in to the ground causes storms in date 11,12 and date 13, the process is a beginning of the global mode; caused blackout according to (Papitashvili, 2020).

Regarding the geomagnetic ground data we selected the following ground stations with specifications as detailed in the following table:

Table (3-1): Show stations information for each CMD, HER and SMA with three globe geographic and geomagnetic (Suliman, 2013).

Station Name/ (Code)	Station sector	Station information				
		geographic		geomagnetic		L shell-Value
		GG Lat	GG Long	GM Lat	GM Lon	
Camden/ (CMD)	Japan/Australia	-34.06	150.67	-44.06	227.92	1.94
Hermanus/ (HER)	Africa/ Europe	-34.34	19.24	-42.29	82.20	1.83
Santa Maria/ (SMA)	Americas	-29.72	-53.72	-19.30	13.24	1.12

CHAPTER FOUR

OBSERVATIONS, DISCUSSION AND CONCLUSION

4.1. Observations

The time sereis geomagnetic data from ground stations: CMD, HER, and SMA, respectively, filterd, and then the FFT were obtained and the dynamic plots were get during the days where SSC occured; see Figure (4-1), which show example of raw, filtered, and dyanmic plots of data from the three stations on the day of the onset of SSC, January 12, 2008, showing a global mode of Pc 5 pulsations (upper part label A shows raw data, filtered data, and Dynamic spectrum of data from CMD stations; and the process is the same for middle labeled B and the lower labeled C, but for HER and SMA stations, respectively). The Dst variations for typical geomagnetic SSC storms is shown for the same day of: January 12, 2008, see Figure(4-2), also in this day a black out happened in Sudan; The SSC storm caused a global mode Pc 5 pulsations, also most probably generated GIC on the ground at low latitude region (Sudan).More evidence for the occurrence of SSC and the impact at low latitude can be verified because of the existence of solar wind activities as the dynamic pressure causes Pc 5 pulsations activity in the ground at low latitude; according to (Papitashvili, 2020), geomagnetic storms, or storm sudden commencement occurred can cause GIC at lower latitudes; and since the process undergoes SSC; then, blackout can be expected.

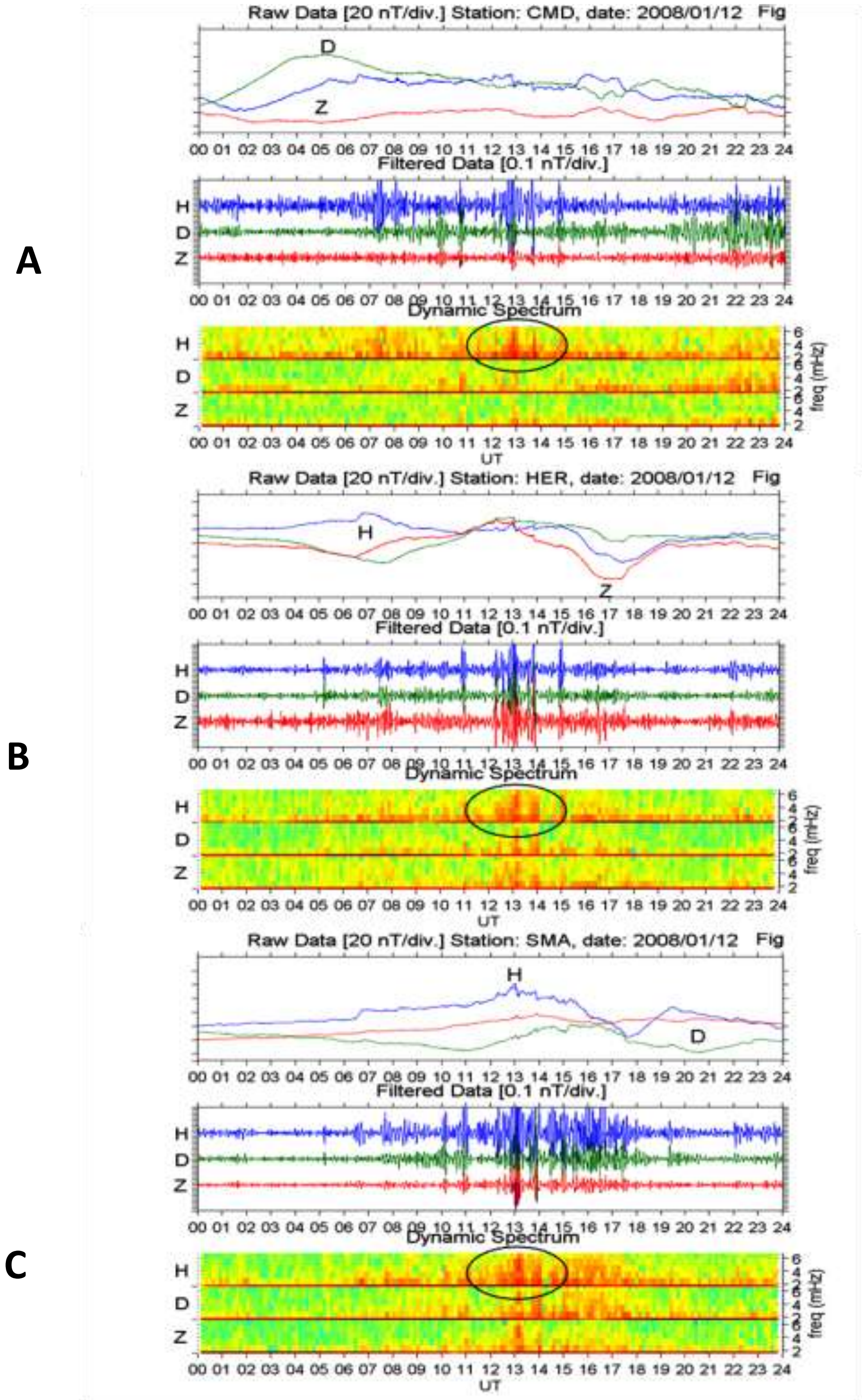


Figure (4-1) shows time sereis geomagnetic data from ground stations: CMD, HER, and SMA, respectively; upper part label A shows raw data, filtered data, and

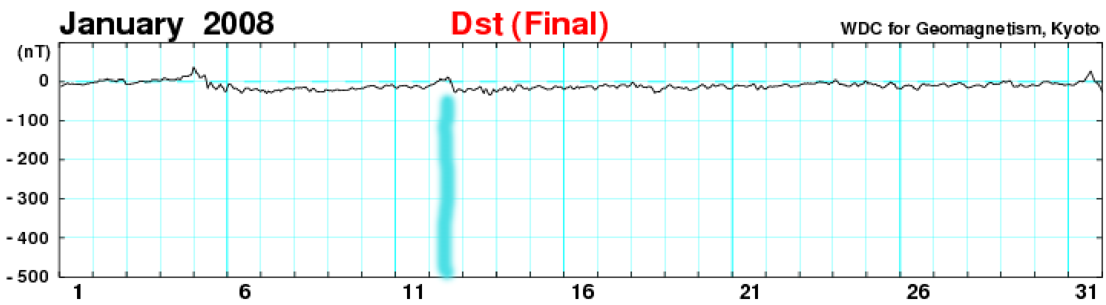
Dynamic spectrum of data from CMD stations; and the process is the same for middle labled Band the lower labled C, but for HERandSMA stations,respectively**.**

Table (4.1): show the occurrence of SSC according to Dst observation in 2008/01/12,that means we observed only one case for storms sudden commencement SSC

years	Date	Dst Observation		Causes	Most likely causes
		SSC Storm	Non Storms		
2008	12/1	1	0	Single Line to ground fault between KNPS-Kuku Y405 due to human error during preventive mains.	SSC storm impact on the ground

1: happen.

0: Non.



Figure(4-2): Shows SSC occurred caused blackout. The Dst observation on January 2008 date 12, the blackout happened in Sudan as obviousely in the figure

4.2. Discussion

Geomagnetic storm is a strong disturbance in the Earth's magnetic field. Through the results that we have obtained them through our observation for Dst which read the minimum value of the storms is-50 we found that there are cases in storms and non storms (quit days) in the day Sid. And the night Sid storms is not considered in our static, such as geomagnetic storms of, 12/January 2008. The SSC started from date 11 Ja. To date 16 it reaches the height in date 13^{th} the height peak indicates the occurrence of GIC due to SSC and the types of storms at that date according to OMNI2

4.3. Conclusion and Remarks

The beginning of SSC occurred can be obtained by checking Dst (Final) and Dst (Provisional); (Abuobaida, 2015). Geomagnetic storms predicable, in February 2009. But as we selected Dst data in (2007-2008), to check the onset of SSC types of storms; it is observed that, three days of SSC occurred in year 2008. Storm is stronger as well as solar wind activity strong. From our investigation of solar wind (speed and pressure), years (2008), we observed the high speed of the plasma causes the flow of the pressure; as a result, storm sudden commencement SSC and Pc5 occurred, these emphasis the global mode occurred, through which blackout can be expected.

In the summary (remarks) we observed an event in which the GIC due to SSC is higher than that during storm main phase. This phenomenon is more observable in low latitude sites which demonstrated by SSC event generated GIC in low latitude, according to CMD, HER and SMA stations we observed GIC and blackout caused by SSC event in difference days in year of (2008). Here we suggest to develop studying GIC due to SSC in Sudan as it’s one of low latitude regions, so that the feedback of interestingly would be a great achievement in the future of study of SSC and its impact in Sudan as a result we can prevents our ground infrastructures such as pipe lines, communication cables, high voltage power transmission system which are harmful space weather effects.

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