CHAPTER I
INTRODUCTION

1.1. An overview:

Space weather is a modern branch of space science, that emerged recently because it has a direct impact on many modern space technology and some ground technology, e.g. communication satellite, ground power grids and petroleum pipelines are all have a malfunction results when exposed to space weather sever changes.

1.2. Space Weather Impact On Earth:

1.2.1. Radio communication and navigation impacts:

Space weather storms modify the density distribution of the ionosphere. Because radio wave propagation depends on the medium the waves move through, a time variable and spatially inhomogeneous ionosphere can severely perturb and degrade ground-to-satellite and satellite-to-ground communication. This can have serious impacts on different system, but is particularly important for high frequency (HF) radio communication and global positioning system (GPS) navigation system.

1.2.2. Pipelines:

Metal will corrode when exposed to a variety of environmental conditions (like moisture and air). Corrosion is enhanced if there is an electrical current flowing through the metal. Along pipeline can be susceptible to enhanced corrosion if electrical currents are allowed to flow across it. Pipelines carry natural gas and oil throughout the arctic region from their source region to terminals at lower latitudes. (Moldwin, 2008)

1.2.3. Power grids:

In last few decades, power generation and distribution have become an interconnected continental-sized industry. Electricity produced by hydroelectric system in Washington State in the United States is shipped to California. Power generated hydro Quebec in eastern Canada can be shipped across the border to power homes in New York. Because of deregulation and this new interconnectivity, system vulnerabilities have increased. A power outage in one part of the grid can quickly propagate to other regions. Overgrown tree branches crossing a high voltage line on Ohio triggered the power outage of 2003 that stretched from Detroit to New York City and left 50 million people in the dark. In March of 1989 a major geomagnetic storm caused an overload of a transformer in Quebec that quickly caused the collapse of the whole system. The transformer had been exposed to induced currents from the geomagnetic storm that exceeded its design capacity and it melted. Transformers can convert high-voltage-low-current electricity into low-voltage-high-current electricity. It is more efficient to run high-voltage electricity long distances, but household appliances need high current. Therefore the electrical system ships the electricity from the power plant to the user at high voltage, and transformers located near the user convert the electricity into useful household or industrial high-current electricity. If the transformers gets more voltage than it is designed for (like induced voltage from enhanced ionospheric currents during a geomagnetic storm), it can fail. Power grids operators therefore must watch the geomagnetic or space weather forecasts and reduce the load on their system during geomagnetic storms. Of course, if storm occurs during a heat wave or cold snap when electricity usage is high, the operators may not have the flexibility to handle the situation 6.7 supplements 89 and then must institute planned rolling “brownouts” or potentially suffer catastrophic blackouts. It is estimated that if a perfect storm occurs during the next solar maximum (a large geomagnetic storm during a heavy electrical usage interval due to a cold or heat wave), hundreds of transformers could be damaged or destroyed. Replacement could take years because transformer manufacturing is expensive and fairly limited. (Moldwin, 2008)

1.3. Problem of this project:

Sun is used to be active than ever thought to be. And couples of phenomena are found to be the cause behind this activity of the sun, e.g. corona mass ejections (CME), sun spots, co rotating interaction regions (CIR's) and flares are phenomena to some extend specify the conditions on space weather. Recently space weather is known as a new field of science deals with variations in the sun-earth coupling system. Hence, sun is thought to be the main source of space weather and scientists are used to formulate to what extend the sun is the space weather source. And because of the impact of space weather to our modern technology and societal economy the question of how to understand the sources of space weather remains under serious investigations. In our project we are trying to review the sun as space weather source.

1.4. Objectives of the project study:

In referring to the problem of this project we set some objectives as follow:

1- To study Sun's phenomena that related to space weather.
2- To study the impact of space weather.
3- To review space weather data products and the international collaborations.

1.5. Outline of the project:

This research project is structured as follow: In chapter one we give brief introduction of space weather and it's influences on the Earth, in chapter two we discuss the Sun's structure, in chapter three we discuss the Earth's space electromagnetism and in chapter four we present the conclusion.

CHAPTER II
THE SUN

2.1. Sun structure:

Astrophysicists classify the Sun as a star of average size, temperature, and brightness; a typical dwarf star just past middle age. It has a power output of about 1026 watts and is expected to continue producing energy at that rate for another 5 billion years` (Hanslmeier, 2008). The Sun is said to have a diameter of 1.4 million kilometers, about 109 times the diameter of Earth, but this is a slightly misleading statement because the Sun has no true “surface.” There is nothing hard, or definite, about the solar disk that we see; in fact, the matter that makes up the apparent surface is so rarified that we would consider it to be a vacuum here on Earth. It is more accurate to think of the Sun’s boundary as extending far out into the solar system, well beyond Earth. In studying the structure of the Sun. Look at Figure2. 1

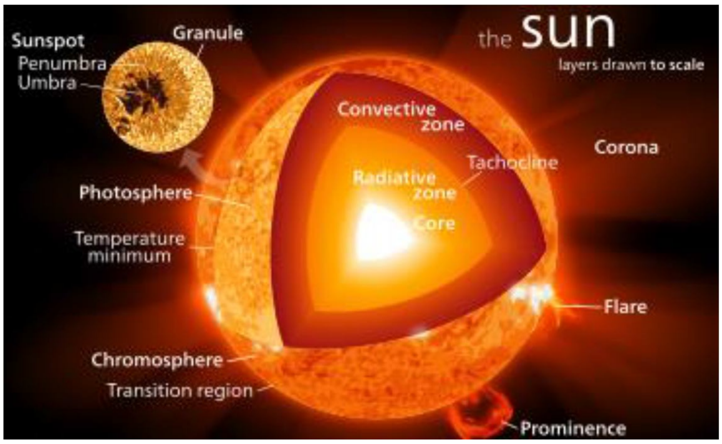


Figure2. 1 Structure of the Sun

2.1.1. The Core:

The core of the Sun is considered to extend from the center to about 20–25% of the solar radius; it has a density of up to 150 g/cm^3 (about 150 times the density of water), and temperature of close to 15.7 million Kelvin (K). By contrast, the Sun's surface temperature is approximately 5,800 K. Recent analysis of SOHO "Solar and Hemispheric Observatory mission" data favors a faster rotation rate in the core than in the rest of the radiative zone. Through most of the Sun's life, energy is produced by nuclear fusion through a series of steps called the p–p (proton–proton) chain; this process converts hydrogen into helium. Only 0.8% of the energy generated in the Sun comes from the CNO "carbon–nitrogen–oxygen" cycle. (MJ Goupil, 2011)

The core is the only region in the Sun that produces an appreciable amount of thermal energy through fusion; 99% of the power is generated within 24% of the Sun's radius, and by 30% of the radius, fusion has stopped nearly entirely. The rest of the star is heated by energy that is transferred outward by radiation from the core to the convective layers just outside. The energy produced byfusion in the core must then travel through many successive layers to the solar photosphere before it escapes into space as sunlight or the kinetic energy of particles. (Phillips, 1995)

2.1.2.Radiative zone:

The radiative zone extends outward from the outer edge of the core interface to the layer or tachocline at the base of convection zone (from 25% of the distance to the surface to 70% of that distance). The radiative zone is characterized by the method of energy transport – radiation. The energy generated in the core is carried by light (photons) that bounces from particle to particle through the radiative zone.

Although the photons travel at the speed of light, they bounce so many times through this dense material that an individual takes about a million years to finally reach the interface layer. The density drops from 20 g/cm^3 (about the density of gold) down to only 0.2 g/cm^3 (less than density of water) from the bottom to the top of the radiative zone. The temperature falls from 7,000,273 k to about 2,000,273 k over the same distance. (Dr. david, 2015)

2.1.3. Convective zone:

In the Sun's outer layer, from its surface to approximately 200,000 km below (70% of the solar radius away from the center), the temperature is lower than in the radiative zone and heavier atoms are not fully ionized. As a result, radiative heat transport is less effective. The density of the gases is low enough to allow convective currents to develop. Material heated at the tachocline picks up heat and expands, thereby reducing its density and allowing it to rise. As a result, thermal convection develops as thermal cells carry the majority of the heat outward to the Sun's photosphere. Once the material cools off at the photosphere, its density increases, and it sinks to the base of the convection zone, where it picks up more heat from the top of the Radiative zone and the cycle continues. At the photosphere, the temperature has dropped to 5,700 K and the density to only 0.2 g/m^3 (about 1/6,000th the density of air at sea level).

The thermal columns in the convection zone form an imprint on the surface of the Sun as the solar granulation and super-granulation. The turbulent convection of this outer part of the solar interior causes “small-scale” dynamos that produce magnetic north and south poles all over the surface of the Sun. The Sun's thermal columns are Bénard cells and take the shape of hexagonal prisms.

2.1.4. Photosphere:

The visible surface of the Sun, the photosphere, is the layer below which the Sun becomes opaque to visible light. Above the photosphere visible sunlight is free to propagate into space, and its energy escapes the Sun entirely. The change in opacity is due to the decreasing amount of ions, which absorb visible light easily. Conversely, the visible light we see is produced as electrons react with hydrogen atoms to produce ions. The photosphere is tens to hundreds of kilometers thick, being slightly less opaque than air on Earth. Because the upper part of the photosphere is cooler than the lower part, an image of the Sun appears brighter in the center than on the edge or limb of the solar disk, in a phenomenon known as limb darkening. The spectrum of sunlight has approximately the spectrum of a black-body radiating at about 6,000 K, interspersed with atomic absorption lines from the tenuous layers above the photosphere. The photosphere has a particle density of ~1023 m^{-3} (about 0.37% of the particle number per volume of the Earth's atmosphere at sea level). The photosphere is not fully ionized—the extent of ionization is about 3%, leaving almost all of the hydrogen in atomic form.

2.1.5. Atmosphere:

The parts of the Sun above the photosphere are referred to collectively as the solar atmosphere. They can be viewed with telescopes operating across the electromagnetic spectrum, from radio through visible light to gamma rays, and comprise five principal zones: the temperature minimum, the chromosphere, the transition region, the corona, and the heliosphere. The coolest layer of the Sun is a temperature minimum region about 500 km above the photosphere, with a temperature of about 4100 K. This part of the Sun is cool enough to allow the existence of simple molecules such as carbon monoxide and water, which can be detected via their absorption spectra.

The chromosphere, transition region, and corona are much hotter than the surface of the Sun. The reason has not been conclusively proven; evidence suggests that Alfven waves may have enough energy to heat the corona.

Above the temperature minimum layer is a layer about 2000 km thick, dominated by a spectrum of emission and absorption lines. It is called the chromosphere from the Greek root chroma, meaning color, because the chromosphere is visible as a colored flash at the beginning and end of total solar eclipses. The temperature in the chromosphere increases gradually with altitude, ranging up to around $20000\,K$ near the top. In the upper part of the chromosphere helium becomes partially ionized. (Russell, 2001)

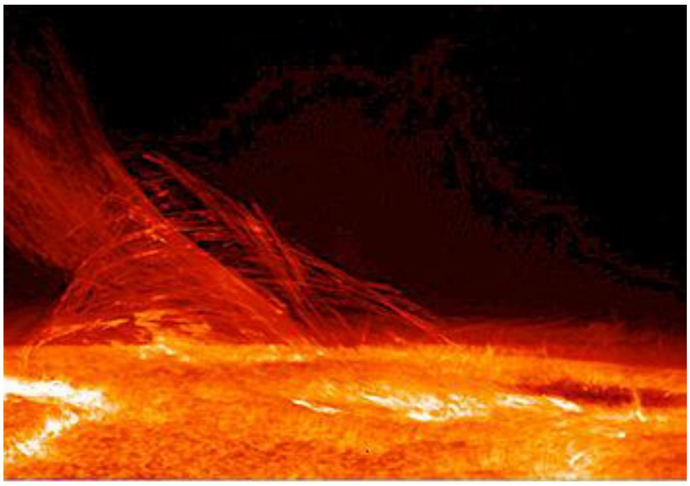


Figure 2.2 Taken by Hinode's Solar Optical Telescope on January 12, 2007, this image of the Sun reveals the filamentary nature of the plasma connecting regions of different magnetic polarity.

Above the chromosphere, in a thin (about 200 km) transition region, the temperature rises rapidly from around 20,000 K in the upper chromosphere to coronal temperatures closer to 1,000,000 K. The temperature increase is facilitated by the full ionization of helium in the transition region, which significantly reduces radiative cooling of the plasma. The transition region does not occur at a well-defined altitude. Rather, it forms a kind of nimbus around chromospheric features such as spicules and filaments, and is in constant, chaotic motion. The transition region is not easily visible from Earth's surface, but is readily observable from space by instruments sensitive to the extreme ultraviolet portion of the spectrum.

The corona is the next layer of the Sun. The low corona, near the surface of the Sun, has a particle density around 1015–1016 m^{-3}. The average temperature of the corona and solar wind is about 1,000,000–2,000,000 K; however, in the hottest regions it is 8,000,000–20,000,000 K While no complete theory yet exists to account for the temperature of the corona, at least some of its heat is known to be from magnetic reconnection. The corona is the extended atmosphere of the Sun, which has volume much larger than the volume enclosed by the Sun's photosphere. Waves at the outer surface of the corona which randomly blow to even further distance from the Sun is called the solar wind, and is one of the Sun’s influences to the whole Solar System.

The heliosphere, the tenuous outermost atmosphere of the Sun, is filled with the solar wind plasma. This outermost layer of the Sun is defined to begin at the distance where the flow of the solar wind becomes superalfvénic—that is, where the flow becomes faster than the speed of Alfven waves, at approximately 20 solar radii (0.1 AU). Turbulence and dynamic forces in the heliosphere cannot affect the shape of the solar corona within, because the information can only travel at the speed of Alfven waves. The solar wind travels outward continuously through the heliosphere, forming the solar magnetic field into a spiral shape, until it impacts the heliopause more than 50 AU from the Sun. In December 2004, the Voyager 1 probe passed through a shock front that is thought to be part of the heliopause. Both of the Voyager probes have recorded higher levels of energetic particles as they approach the boundary. (paschmann, outer magnetospheric boundaries: cluster results, 2005)

CHAPTER III

EARTH’S SPACE ELECTROMAGNETISM

3.1. Earth’s Magnetic Field:

Earth is largely protected from the solar wind, a stream of energetic charged particles emanating from the Sun, by its magnetic field, which deflects most of the charged particles. Some of the charged particles from the solar wind are trapped in the Van Allen radiation belt. A smaller number of particles from the solar wind manage to travel, as though on an electromagnetic energy transmission line, to the Earth's upper atmosphere and ionosphere in the auroral zones. The only time the solar wind is observable on the Earth is when it is strong enough to produce phenomena such as the aurora and geomagnetic storms. Bright auroras strongly heat the ionosphere, causing its plasma to expand into the magnetosphere, increasing the size of the plasma geosphere, and causing escape of atmospheric matter into the solar wind. Geomagnetic storms result when the pressure of plasmas contained inside the magnetosphere is sufficiently large to inflate and thereby distort the geomagnetic field.

The solar wind is responsible for the overall shape of Earth's magnetosphere, and fluctuations in its speed, density, direction, and entrained magnetic field strongly affect Earth's local space environment. For example, the levels of ionizing radiation and radio interference can vary by factors of hundreds to thousands; and the shape and location of the magnetopause and bow shock wave upstream of it can change by several Earth radii, exposing geosynchronous satellites to the direct solar wind. These phenomena are collectively called space weather. The mechanism of atmospheric stripping is caused by gas being caught in bubbles of magnetic field, which are ripped off by solar winds Variations in the magnetic field strength have been correlated to rainfall variation within the tropics. (AFP, 2009)

3.1.1 Field characteristics:

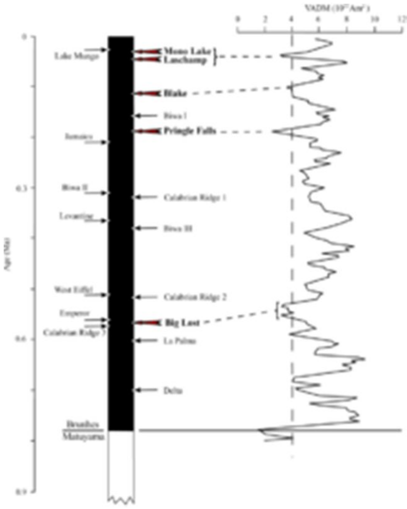
The strength of the field at the Earth's surface ranges from less than 30 Microtesla (0.3 gauss) in an area including most of South America and South Africa to over 60 Microtesla (0.6 gauss) around the magnetic poles in northern Canada and south of Australia, and in part of Siberia. The average magnetic field strength in the Earth's outer core was measured to be 25 Gauss, 50 times stronger than the magnetic field at the surface.

The field is similar to that of a bar magnet. The Earth's magnetic field is mostly caused by electric currents in the liquid outer core. The Earth's core is hotter than 1043 K, the Curie point temperature above which the orientations of spins within iron become randomized. Such randomization causes the substance to lose its magnetization.

Convection of molten iron within the outer liquid core, along with a Coriolis effect caused by the overall planetary rotation, tends to organize these "electric currents" in rolls aligned along the north-south polar axis. When conducting fluid flows across an existing magnetic field, electric currents are induced, which in turn create another magnetic field. When this magnetic field reinforces the original magnetic field, a dynamo is created that sustains itself. This is called the Dynamo Theory and it explains how the Earth's magnetic field is sustained.

Another feature that distinguishes the Earth magnetically from a bar magnet is its magnetosphere. At large distances from the planet, this dominates the surface magnetic field. Electric currents induced in the ionosphere also generate magnetic fields. Such a field is always generated near where the atmosphere is closest to the Sun, causing daily alterations that can deflect surface magnetic fields by as much as one degree. Typical daily variations of field strength are about 25 Nanotesla (nT) (i.e. ~ 1:2,000), with variations over a few seconds of typically around 1 nT (i.e. ~ 1:50,000).

3.1.2 Magnetic field variations:



Geomagnetic variations since last reversal.

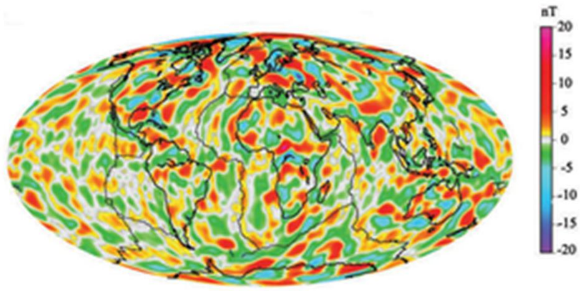
The currents in the core of the Earth that create its magnetic field started up at least 3,450 million years ago. (Usui, Tarduno, Watkeys, Hofmann, & Cottrell, 2009)

Magnetometers detect minute deviations in the Earth's magnetic field caused by iron artifacts, kilns, some types of stone structures, and even ditches and midden in archaeological geophysics. Using magnetic instruments adapted from airborne magnetic anomaly detectors developed during World War II to detect submarines, the magnetic variations across the ocean floor have been mapped. The basalt — the iron-rich, volcanic rock making up the ocean floor — contains a strongly magnetic mineral (magnetite) and can locally distort compass readings. The distortion was recognized by Icelandic mariners as early as the late 18th century. More important, because the presence of magnetite gives the basalt measurable magnetic properties, these magnetic variations have provided another means to study the deep ocean floor. When newly formed rock cools, such magnetic materials record the Earth's magnetic field.

Frequently, the Earth's magnetosphere is hit by solar flares causing geomagnetic storms, provoking displays of aurora. The short-term instability of the magnetic field is measured with the K-index.

Recently, leaks have been detected in the magnetic field, which interact with the Sun's solar wind in a manner opposite to the original hypothesis. During solar storms, this could result in large-scale blackouts and disruptions in artificial satellites. (Thompson, 2008)

3.1.3Magnetic field detection:



Deviations of a magnetic field model from measured data, data created by satellites with sensitive magnetometers

The Earth's magnetic field strength was measured by Carl Friedrich Gauss in 1835 and has been repeatedly measured since then, showing a relative decay of about 10% over the last 150 years. The Magsat satellite and later satellites have used 3-axis vector magnetometers to probe the 3-D structure of the Earth's magnetic field. The later Ørsted satellite allowed a comparison indicating a dynamic geodynamo in action that appears to be giving rise to an alternate pole under the Atlantic Ocean west of S. Africa

Governments sometimes operate units that specialize in measurement of the Earth's magnetic field. These are geomagnetic observatories, typically part of a national Geological Survey, for example the British Geological Survey's Eskdalemuir Observatory. Such observatories can measure and forecast magnetic conditions that sometimes affect communications, electric power, and other human activities. The International Real-time Magnetic Observatory Network, with over 100 interlinked geomagnetic observatories around the world has been recording the Earth's magnetic field since 1991.

The military determines local geomagnetic field characteristics, in order to detect anomalies in the natural background that might be caused by a significant metallic object such as a submerged submarine. Typically, these magnetic anomaly detectors are flown in aircraft like the UK's Nimrod or towed as an instrument or an array of instruments from surface ships.

Commercially, geophysical prospecting companies also use magnetic detectors to identify naturally occurring anomalies from ore bodies, such as the Kursk Magnetic Anomaly.

Animals including birds and turtles can detect the Earth's magnetic field, and use the field to navigate during migration. Cows and wild deer tend to align their bodies north-south while relaxing, but not when the animals are under high voltage power lines, leading researchers to believe magnetism is responsible. (Burda, Begall, Cerveny, Neef, & Nemec, 2009).

3.2. Earth's Magnetosphere:

A magnetosphere is the region surrounding a planet where the planet's magnetic field dominates. Because the ions in the solar plasma are charged, they interact with these magnetic fields, and solar wind particles are swept around planetary magnetospheres. Life on Earth has developed under the protection of this magnetosphere.

The shape of the Earth’s magnetosphere is the direct result of being blasted by solar wind.

Solar wind compresses its sunward side to a distance of only 6 to 10 times the radius of the Earth.

A supersonic shock wave is created sunward of Earth somewhat like a sonic boom. This shock wave is called the bow shock. Most of the solar wind particles are heated and slowed at the bow shock and detour around the Earth. Solar wind drags out the night-side magnetosphere to possibly 1000 times Earth’s radius; its exact length is not known. This extension of the magnetosphere is known as the magneto tail. Many other planets in our solar system have magnetospheres of similar, solar wind-influenced shapes. (Christian, 2012)

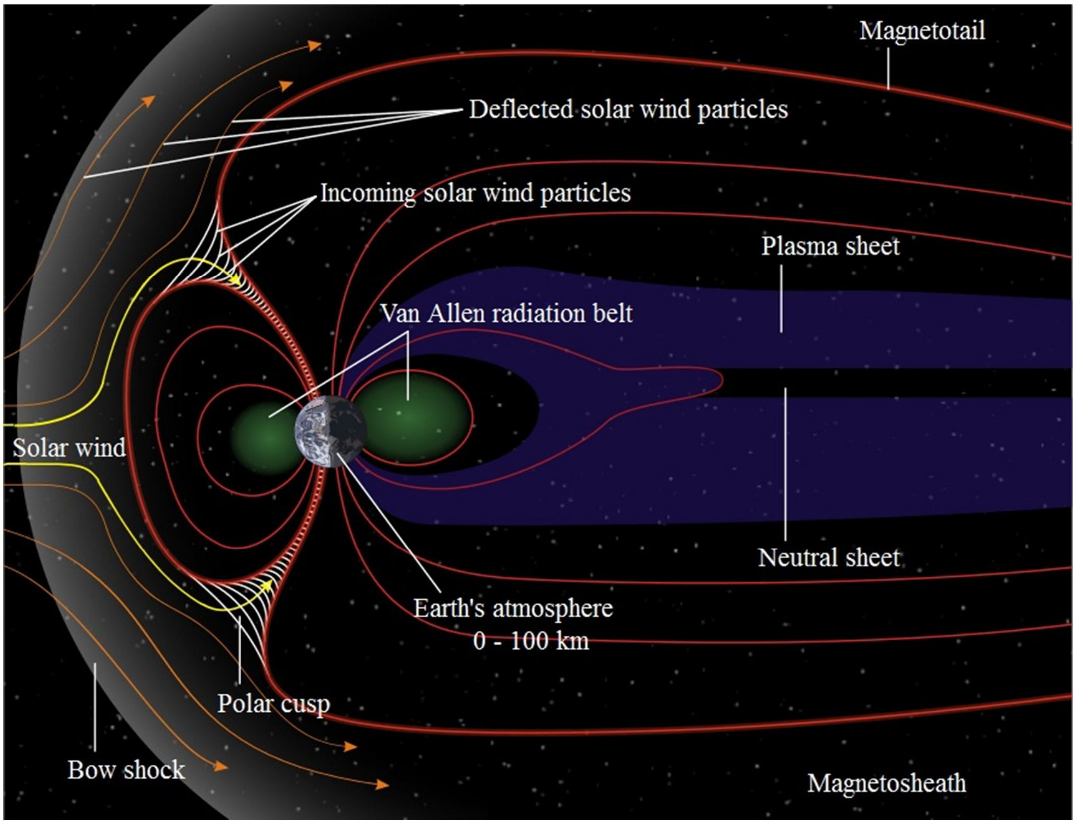


Figure (3.1): Show Earth’s Magnetosphere Structure; after: (Aaron, 2008)

3.2.1. Bow Shock:

When the supersonic flow of the solar wind first encounters the earth’s magnetic field it creates a shock wave. This interaction compresses the magnetosphere on the dayside and shapes it into an elongated teardrop on the nightside. The ultimate consequences of this interaction are far-reaching disturbances in our atmosphere, such as magnetic substorms that interfere with power transmission and communications and produce the spectacle of the polar auroras. The wave is called the bow shock, in analogy to the bow wave of a boat, and is a jump in plasma density, temperature, and magnetic field associated with the transition from supersonic to subsonic flow. So turbulent is the shock that we have been unable to model the highly nonlinear processes that determine its structure. But progress has been made in modeling the foreshock region (upstream of the bow shock) where energetic protons reflected from the shock black toward the sun may help to heat, decelerate, and deflect the solar wind. Earth's bow shock about 17 kilometers (11 mi) thick and located about 90,000 kilometers (56,000 mi) from the planet. (Stand W. &., 1975)

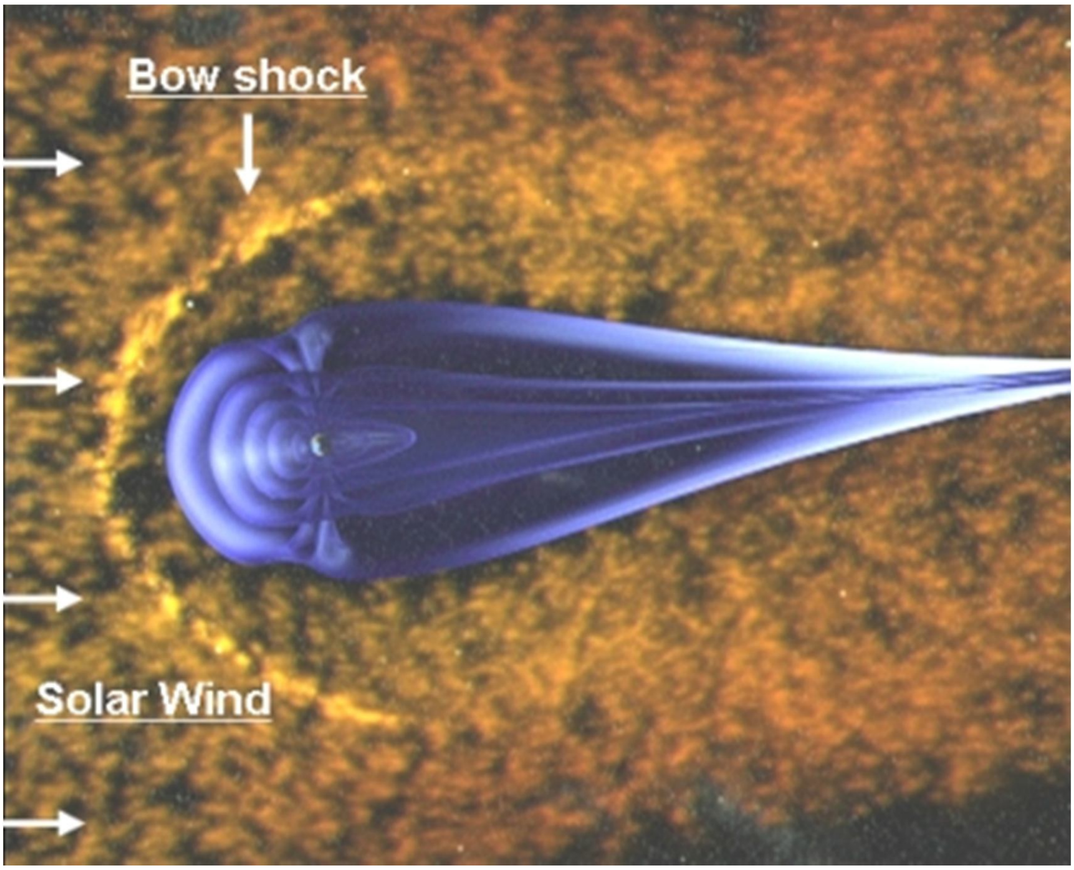


Figure (3.2) Earth's Bow Shock; After**:** (Noordwijk, 2009)

3.2.2. Magnetosheath:

The Magnetosheath is the region of space between the magnetopause and the bow shock of a planet's magnetosphere. The regularly organized magnetic field generated by the planet becomes weak and irregular in the magnetosheath due to interaction with the incoming solar wind, and is incapable of fully deflecting the highly charged particles. The density of the particles in this region is considerably lower than what is found beyond the bow shock, but greater than within the magnetopause, and can be considered a transitory state. Scientific research into the exact nature of the magnetosheath has been limited due to a longstanding misconception that it was a simple byproduct of the bow shock/magnetopause interaction and had no inherently important properties of its own. Recent studies indicate, however, that the magnetosheath is a dynamic region of turbulent plasma flow that may play an important role in the structure of the bow shock and the magnetopause, and may help to dictate the flow of energetic particles across those boundaries. The Earth's magnetosheath typically occupies the region of space approximately 10 … the earth, extending signific … pressure of the solar wind. T … heath does depend on variabl …

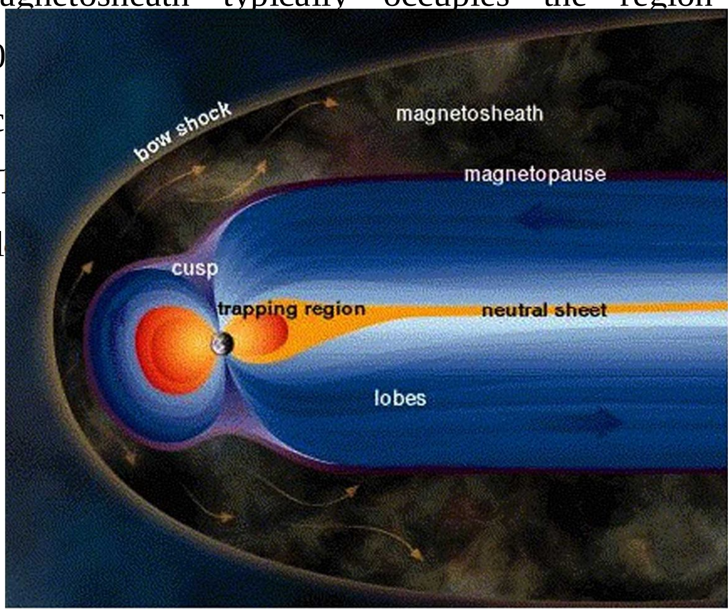


Figure (3.3) Magnetosheath of earth; after: (MICHEL, 2010)

3.2.3. Magnetopause:

The magnetopause is the abrupt boundary between a magnetosphere and the surrounding plasma. For planetary science, the magnetopause is the boundary between the planet's magnetic field and the solar wind. The location of the magnetopause is determined by the balance between the pressure of the dynamic planetary magnetic field and the dynamic pressure of the solar wind. As the solar wind pressure increases and decreases, the magnetopause moves inward and outward in response. Waves (ripples and flapping motion) along the magnetopause move in the direction of the solar wind flow in response to small scale variations in the solar wind pressure and to Kelvin-Helmholtz instability. The magnetic boundary between the Earth's field and the solar wind, named the magnetopause, has a bullet-shaped front, gradually changing into a cylinder. Its cross-section is approximately circular. Distances in the magnetosphere are often measured in Earth radii (RE), with one Earth radius amounting to 6371km or 3960 miles. In these units, the distance from the Earth's center to the "nose" of the magnetosphere is about 10.5 RE and to the flanks abreast of the Earth about 15 RE, while the radius of the distant tail is 25-30 RE. By way of comparison, the moon's average distance is about 60 RE. these, though, are just averages: the pressure of the solar wind rises and falls, and as it does, the magnetopause shrinks or expands. For instance, when the boundary is hit by a fast flow from a coronal mass ejection, the "nose" is pushed in, occasionally (a few times a year, usually) even past the synchronous orbit at 6.6 RE. (Chao J. K.-H., Models for the size and shape of the Earth's magnetopause and bow shock,, 2002)

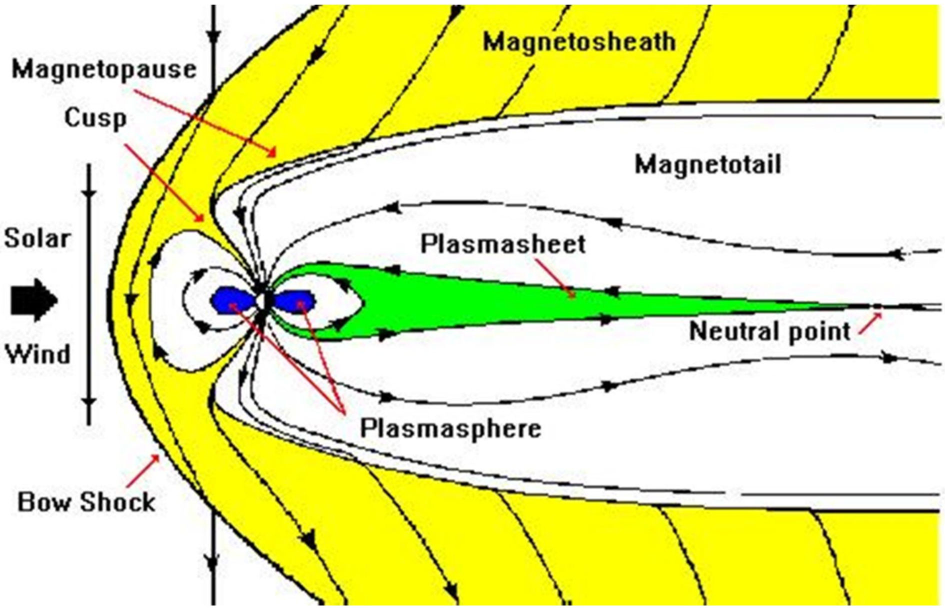


Figure (3.4) Earth's Magnetopause

3.2.4. The Tail of the Magnetosphere:

In contrast to the dayside magnetosphere, compressed and confined by the solar wind, the night side is stretched out into a long “magnetotail”. The part of the magnetosphere is quite dynamic, large changes can take place there and ions and electrons are often energized.

The magnetotail is also the main source of the polar aurora. Even before the space age observers noted that in the arctic winter, when the sky was dark much of the time, the brightest auroras were seen in the hours around midnight. It was widely believed then that auroral electrons came from the sun, and the fact that aurora seemed concentrated on the side facing away from the sun puzzled everyone. Those observations made much more sense after satellites discovered and mapped the magnetosphere's long tail. (Stern, 2006)

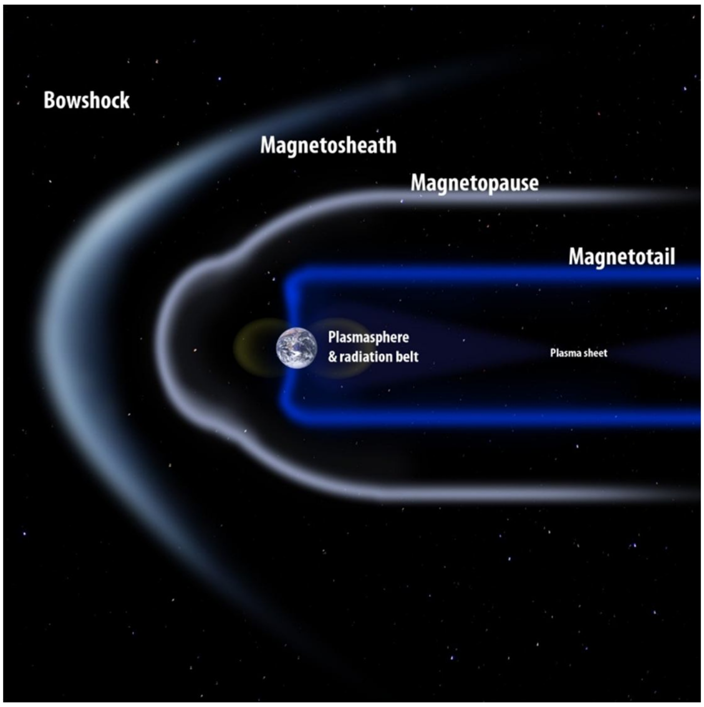


Figure (3.5) The Tail of the Magnetosphere

3.2.5. The Tail Lobes:

Most of the volume of the tail is taken up by two large bundles of nearly parallel magnetic field 9lines.

The bundle north of the equator points earthwards and leads to a roughly circular region including the northern magnetic pole , while the southern bundle points away from Earth and is linked to the southern polar region.

These two bundles, known as the "tail lobes", extend far from Earth:ISEE-3 and Geotail found them well-defined even at 200-220 RE (Earth radii) Earth. At those distances the lobes are already penetrated by some solar wind plasma, but near Earth they are almost empty. One may compare typical plasma densities:

Table (3-1) Comparing between plasma density in differ region (Stern, 2006)

Plasma Region	**Density**
Solar wind near Earth	6 ions/cm^3
Dayside outer magnetosphere	1 ion/cm^3
"Plasma sheet" separating tail lobes	0.3– 0.5 ions/cm^3
Tail lobes	0.01 ion/cm^3

This extremely low density suggests that field lines of the lobe ultimately connect to the solar wind, somewhere far downstream from Earth. Ions and electrons then can easily flow away along lobe field lines, until they are swept up by the solar wind; but very, very few solar wind ions can oppose the wind's general flow and head upstream, towards Earth. With such a one-way traffic, rather little plasma remains in the lobes. (Stern, 2006)

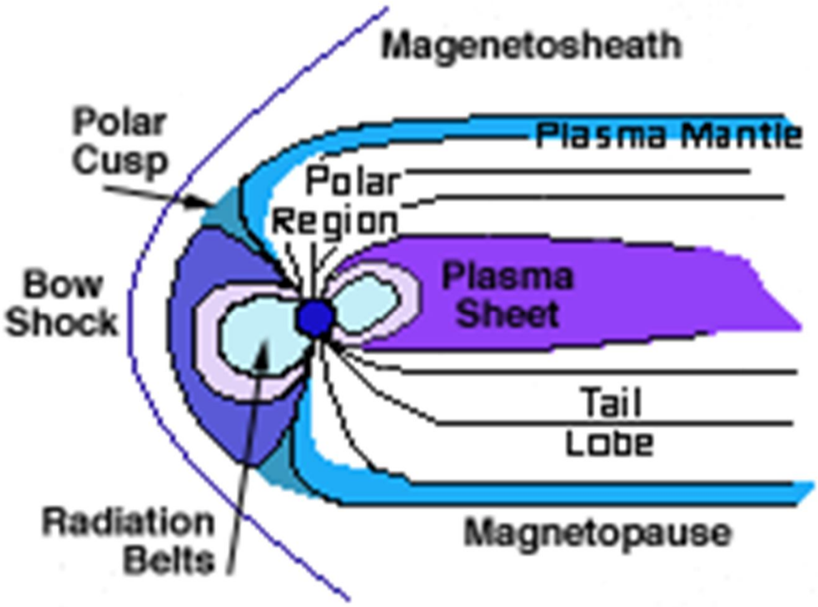


Figure (3.6) The tail lobes of earth; after (Stern, 2006)

3.2.6. The Plasma Sheet:

A magnetosphere is produced by the interaction of a stream of charged particles, such as solar wind, with a planet's (or similar body's) magnetic field. All planets with intrinsic magnetic fields, including Earth, are surrounded by a magnetosphere. The plasma sheet is just that, a sheet of plasma that extends down the magnetotail dividing the two lobes of the Earth's magnetic field. This outer plasma is hotter than the plasma in the plasmasphere, but is considered low energy when compared to the particles in the Van Allen radiation belts. In the magnetosphere, the plasma sheet is a sheet-like region of denser (0.3-0.5 ions/cm3 versus 0.01-0.02 in the lobes) hot plasma and lower magnetic field near the equatorial plane, between the magnetosphere's north and south lobes. (C. E. I., 1972)

3.2.7. Plasmasphere:

The plasmasphere, or inner magnetosphere, is a region of the Earth magnetosphere consisting of low energy (cool) plasma. It is located above the ionosphere. The outer boundary of the plasmasphere is known as the plasma pause, which is defined by an order of magnitude drop in plasma density. The plasmasphere has been regarded as a well behaved cold plasma with particle motion dominated entirely by the magnetic field and hence co rotating with the Earth. In contrast, recent satellite observations have shown that density irregularities such as plumes or bite outs may from. It has also been shown that the plasmasphere does not always co-rotate with the Earth. The plasma of the magnetosphere has many different levels of temperature and concentration. The coldest magnetosphere plasma is most often found in the plasmasphere, a donut-shaped region surrounding the Earth's middle. But plasma from the plasmasphere can be detected throughout the magnetosphere because it gets blown around by electric and magnetic field. Data gathered by the twin Van Allen probes show that the plasmasphere also limits highly energetic ultrarelativistic electrons from cosmic and solar origin from reaching low earth orbits and the surface of the planet. (C. E. I., 1972)

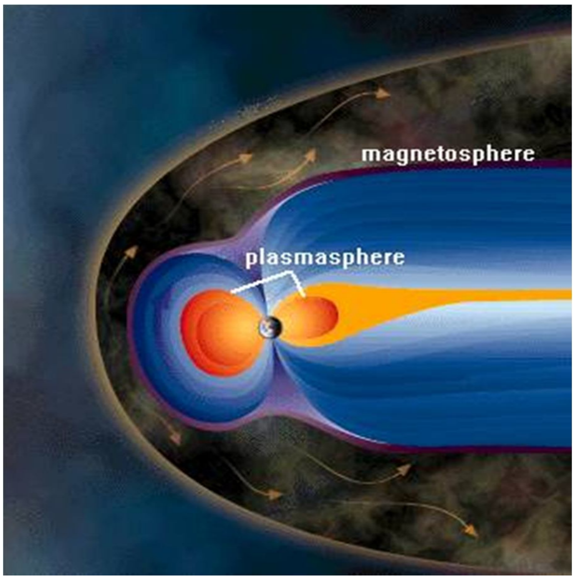


Figure (3.7) Earth's plasmasphere; after: (Russel.C, 2008)

3.2.8. Van Allen radiation belt:

Doughnut-shaped zones of highly energetic charged particles trapped at high altitudes in the magnetic field of Earth. The zones were named for James A. Van Allen, the American physicist who discovered them in 1958, using data transmitted by the U.S. Explorer satellite.

The Van Allen belts are most intense over the Equator and are effectively absent above the poles.

No real gap exist between the two zones; they actually merge gradually, with the flux of charged particles showing two region of maximum density. The inner region is centered approximately 3,000 km (1,860 miles) above the terrestrial surface. The outer region of maximum density is centered at an altitude of about 15,000 to 20,000 km (9300 to 12,400 miles), though some estimates place it as far above the surface as six Earth radii (about 38,000 km [23,700 miles]).

The inner Van Allen belt consists largely of highly energetic protons, with energy exceeding 30,000,000 electron volts. The peak intensity of these protons is approximately 20,000 particles per second crossing a spherical area of one square cm in all directions. It is believed that the protons of the inner belt originate from the decay of neutrons produced when high-energy cosmic rays from outside the solar system collide with atoms and molecules of Earth's atmosphere. Some of the neutrons are ejected back from the atmosphere; as they travel through the region of the belt, a small percentage of them decay into protons and electrons. These particles move in the spiral paths along the lines of force of Earth's magnetic field. As the particles approach either of the magnetic poles, the increase in the strength of the field causes them to be reflected. Because of this so-called magnetic mirror effect, the particles bounce back and forth between the magnetic poles. Over time, they collide with atoms in the thin atmosphere, resulting in their removal from the belt.

The outer Van Allen belt contains charged particles of both atmospheric and solar origin, the latter consisting largely of helium ions from the solar wind (steady stream of particles emanating from the sun). The protons of the outer belt have much lower energies than those of the inner belt, and their fluxes are much higher. The most energetic particles of the outer belt are electrons, whose energies reach up to several hundred million electron volts. (Danny Summers I. R., 2013)

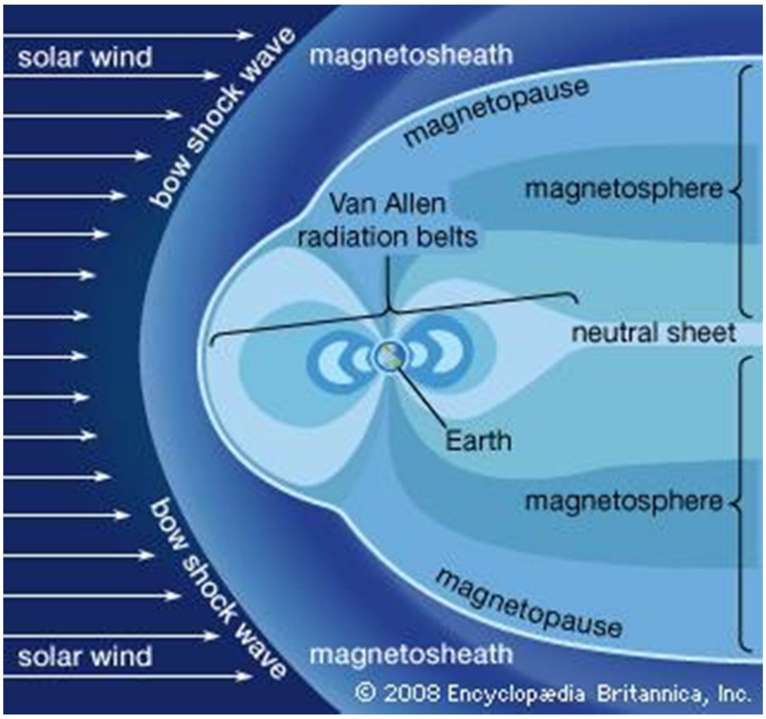


Figure3.8 Van Allen Radiation Belts;

CHAPTER FOUR

4.1 Summary:

Space weather is a modern branch of space science, that emerged recently because it has a direct impact on many modern space technology and some ground technology, e.g. communication satellite, ground power grids and petroleum pipelines are all have a malfunction results when exposed to space weather sever changes.

We also introduced the properties of stars and the properties of the sun as a typical star; then we talked about the structure of the sun which is including the core, radiative zone, convection zone and the magnetic field.

We discuss the earth’s magnetosphere Structure which is including bow shock, magnetosheath, magnetopause and magnetotail; a magnetosphere is the region surrounding a planet where the planet's magnetic field dominates. Because the ions in the solar plasma are charged, they interact with these magnetic fields, and solar wind particles are swept around planetary magnetospheres. Life on Earth has developed under the protection of this magnetosphere.

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