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# "The Role of Solar Wind on Earth's Magnetic Field and Geomagnetic Field Variations of Morphology"

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## Abstract

The magnetosphere is shaped like a comet in response to the dynamic pressure of the solar wind. It is compressed on the side toward the sun to about 10 Earth radii ands is extended tail-like on the side away from the Sun 60-100 Earth radii. The magnetosphere deflects the flow of most solar wind particles around the Earth, There are two kinds of transient variation, the first includes relatively small and regular daily variation, and the second is the disturbances of a more violent nature known as geomagnetic storms. Alexander von Humboldt was the first to discover the dependency of magnetic intensity on latitude and observed the geomagnetic field at various locations at Earth. The variation in geomagnetic field is known as geomagnetic storm. The magnetosphere is filled with tenuous plasmas. **(Chen,J.1998)[1]**. There was a technical difficulty observed by scientists, that the solar wind/interplanetary magnetic field system is not homogenous observed at any given time by two or more satellite. We hope that some future space mission will solve this problem.

## Introduction

The angle between the field lines and the radial direction is about 45 degrees.Due to the supersonic nature of the solar wind,The earth's magnetic field is confined by the dynamo pressure of solar wind in a magnetospheric cavity that has a long tail consisting of two antiparallel bundles of magnetic flux that stretch in antisolar direction, known as magnetosphere.The magnetosphere shrinks when the solar wind blows harder**(Giles,B. L.1993)[2]**.When the solar wind abates, the magnetosphere expands. The solar wind contains mass and momentum both.During a geomagnetic storm main phase, charged particles in the near-earth plasma sheet are energized and injected deeper into the inner magnetosphere the Van Allen belts and the plasmasphere. Magnetosheath-like plasmas have been found at several regions in the magnetosphere.The common characteristics of plasma mantle are that they have magnetosheath-like energy spectra and flow in the anti-solar direction.The magnetosphere has two domains where relatively dense plasmas are located. In the first plasmasphere occupies a part of the inner magnetosphere and its location varies with a fraction of local time.The plasmasphere is surrounded by another domain known as plasma sheet.The plasma sheet is a sheet-like distribution (**Barlow,W.H.1848**)[3].Centered on the midplane of the magnetotail called the ‘neutral sheet.The plasma particles from inner or central plasma sheet (CPS) contribute significantly in exciting the diffuse auroral luminosity, The geomagnetospheric cavity thus measures some 10 Earth radii in the solar direction and a considerable, but uncertain (extending from 60 to 100 $R_E$), distance in the direction away from the Sun.

## The Terrestrial Magnetosphere

The pressure of the magnetic field and the plasma establishes equilibrium with the solar wind. The magnetosphere shrinks when the solar wind blows harder. When the solar wind abates, the magnetosphere expands. The solar wind contains mass and momentum both. It exerts a force outward from the Sun on every obstacle in its path. Passing through the shock, which ranges in thickness varying from 100 km to 2 Earth radii, the solar wind is slowed, compressed, and heated. **Figure. 1.**

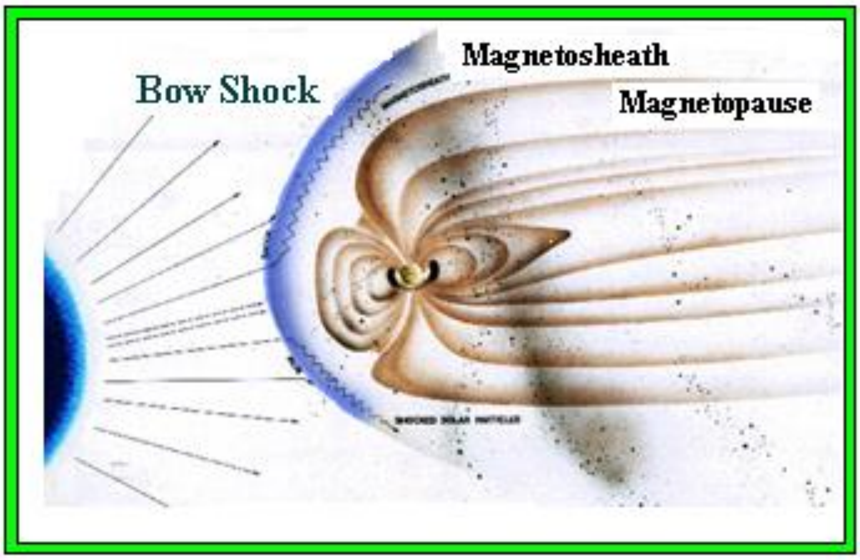


**Figure 1.**Shows the formation of the bow shock front. In this figure bow shocks are formed on frontal surface of the magnetosphere, where the solar wind has its first impact with geomagnetic field. The magnetosheath and magnetopause are also explained in this figure.

The earth's magnetic field is such an obstacle.Because the magnetic fields of the Earth and the solar wind are 'frozen in` to their respective plasma by the high electrical conductivity of the plasmas. Shock waves are formed in front of the earth's magnetosphere, and:

1 Drives the magnetospheric convection system and energizes much of the plasma on the earth's magnetic field lines.

2 Drives field line resonance and other geomagnetic pulsations.

3 Creates geomagnetic activity.

4 Heats the polar upper atmosphere.

5 Drives large neutral atmospheric winds.

These changes in the solar wind plasma parameters (density, velocity, etc.) and interplanetary magnetic field (especially direction in relation to earth's own field) are very important for the study of magnetospheric and ionospheric physics, and the scientific community tries to have continuous monitoring of these parameters via satellites like IMP-8, ISEE, and Wind.The earth's magnetic field is confined by the dynamo pressure of solar wind in a magnetospheric cavity that has a long tail consisting of two antiparallel bundles of magnetic flux that stretch in antisolar direction, outer boundary of the cavity is known as magnetopause. The impact of a unidirectionally, streaming, unmagnetized plasma upon a dipole field was first studied by Chapman and Ferraro in a series of papers during 1931-33.

## Bow the Shocks

The frontal surface of the magnetosphere, where the solar wind has its first impact with geomagnetic field, is known as bow shock front, which are shown in the bow shock is a shock wave formed at a dista**.**In front of the magnetopause by encounter of the supersonic solar wind with the obstacle on earth's magnetic field. The formation of the magnetosphere and its different regions such as bow shock, magnetopause, magnetosheath and magnetotail are shown in **Figure.2.**

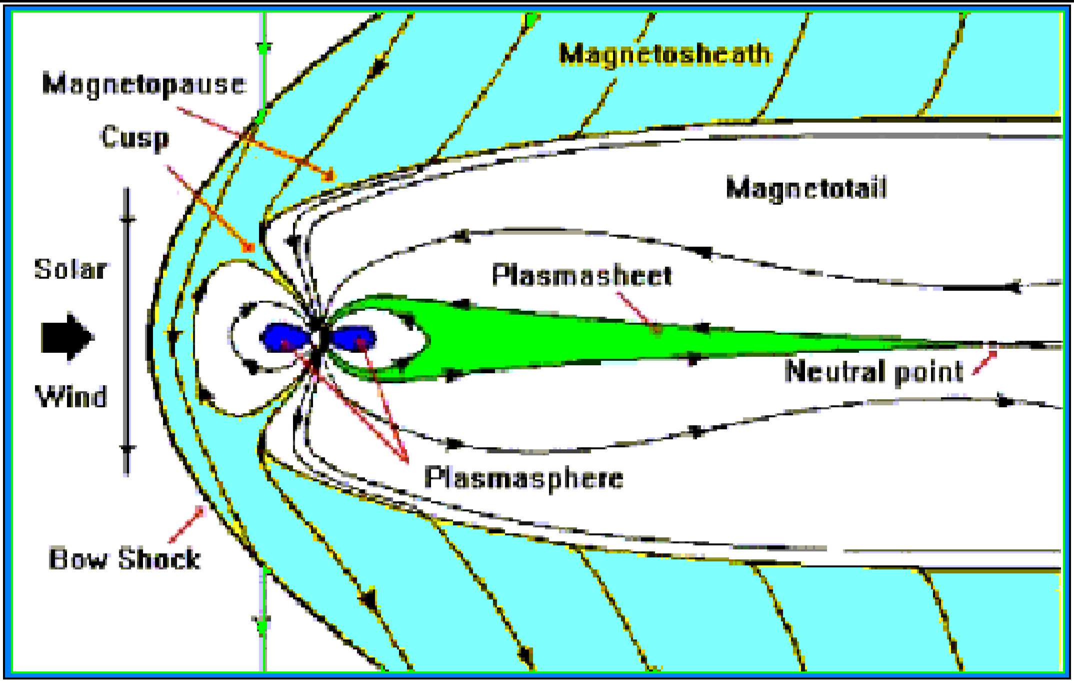


**Figure.2.** Shows the formation of the magnetosphere and its different regions such as bow shock, magnetopause, magnetosheath, magnetotail, cusp,plasma sheet, plasmasphere and neutral point.

- **Chapman-Ferraro model** - An electric current is induced in the cloud as it first encounters the magnetic field of the Earth. This is a problem of boundary between collisionless unmagnetized plasma and a vacuum field. Essentially, equilibrium occurs when the plasma pressure balance the magnetic field pressure.
- **Tear Drop model** - Magnetosphere consist of closed field lines in which the interplanetary and magnetospheric plasma is perfectly conducting.
- **Reconnection model** (Open or Dungey model) - When the southward directed interplanetary magnetic field lines convected by the solar wind from an interaction region on the day side either join up with or reconnects with the Earth's magnetic field in the subsolar regions. This model is very useful to obtain the topology of magnetic field and motion of plasma flow near the neutral point.

The region downstream of the bow shock, between the shock and the magnetopause that is occupied by the shocked solar wind plasma is known as the magnetosheath. Generally, three waves are needed for the magnetospheric disturbances, termed as: slow magnetosonic wave, intermediate wave and fast magnetosonic wave back upstream **(Crooker,N.U.1994)**[4].These back streaming particles generate waves through various instabilities and these waves are then convected with the solar wind flow toward the shock. Still other waves originate as newly created ions scatter and thermalize both in the extended coronas surrounding comets and in the exospheres of unmagnetized planets.They provide a direct entry for the magnetosheath plasma into the magnetosphere The high-altitude cusp, which is often called the exterior cusp, can be considered to be a part of the magnetospheric boundary layer system. The low-altitude cusp is the dayside region in which the entry of magnetosheath plasma is directed at low altitudes. Measurements have shown, that the cusp is highly confined region, extending about 2.5 hours in local time, but only about one degree or less in latitude.**(Gosling J.T.1990)**[5] **.**Due to strong dependence of the cusp position on IMF conditions, the statistical studies tend to show larger cusp regions. The magnetosheath plasma penetrating into the low-altitude cusp is responsible for the dayside auroral precipitation. Measurements by the Polar satellite have shown that ions in the MeV range are also present**.**. Many types of waves and turbulent flows which have also access to the ionosphere via the cusp, are given as:

- Solar wind variations generated in the foreshock upstream of the bow shock.
- Radiation from the parallel and perpendicular shocks.
- Magnetosheath turbulence and waves.
- Magnetopause boundary variations.
- Waves and particle variations, which take place in the boundary layers just inside the magnetopause.

The low-altitude cusp is the focus of these phenomena and ground observations are comprised of their superposition.

## The Earth's Radiation Belts

James Van Allen discovered the earth's radiation belts of trapped radiation near the Earth in 1958. The radiation belts of the Earth are made up of electrons, protons and heavier atomic ions. These charge particles are trapped inside the magnetosphere when its kinetic energy ($1/2\ \rho V^2$) is less than the dipole field energy ($B^2/8\pi$) and forms the earth's radiation belts. Van Allen had been exploring the upper atmosphere of the Earth with balloons that could measure radiation levels in the atmosphere. Van Allen and his team placed a Geiger counter and an altimeter on Explorer I, the first American spacecraft, to take radiation readings at different heights. They observed and mapped the regions appearing as zero radiation level, and named as the earth's radiation belts. The radiation belts, like the plasmasphere, are toroidally shaped. There is an outer and an inner radiation belts. During the International Geophysical Year (1957-58), the various satellites Explorers, Pioneers and Sputniks, using the Geiger tube, **(Bargatze,L.F.Baker,D.N.1985)**[6] .Discovered two radiation belts around the Earth: (**i**) the inner, Kidney-shaped belt which was relatively stable and is postulated at about 1.5 $R_E$, consisting mainly of protons with energies ($E_p \geq 30$ Mev) and (**ii**) the outer, crescent-shaped belt lies between 3-4 $R_E$, which was relatively unstable and having large fluctuations in intensities of energetic electrons ($E_e \geq 1.6$ Mev) [Van Allen et al., 1958]. The outer and inner radiation belts are separated by a region of low counting rate, called the slot. Besides the radiation belts the magnetosphere is also filled with hot plasma, which forms the plasmasphere occupying a small part of the trapping regions. The inner magnetospheric currents, **Figure.3.**

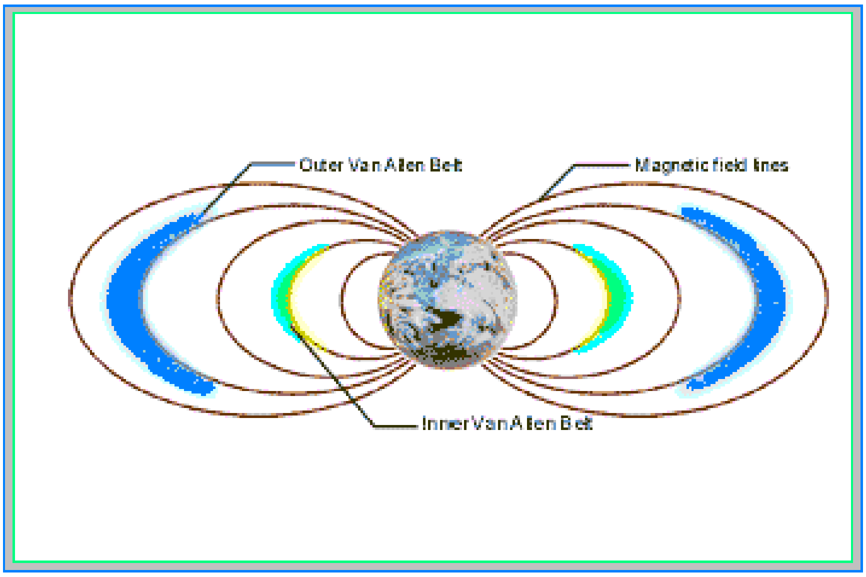


**Figure 3.**Described the formation of the Van Allen Earth's radiation belts of trapped radiation near the Earth. The inner and outer belts are also sketched in this figure.

## Magnetospheric Dynamics

The magnetospheric dynamics is principally concerned with magnetic reconnection between solar wind and earth's magnetic field. The solar wind and interplanetary magnetic field have intimate control over the shape and dynamics of the earth's magnetosphere as well as the level of geomagnetic activity(**Gosling,J.T.1996**)[7].Dungey postulated the mechanism of magnetic reconnection between geomagnetic and interplanetary magnetic field in 1961. The magnetic flux is transported from the dayside of magnetosphere to the night side. This magnetic flux builds up in the tail until reconnection occurs there too and returns the magnetic flux to the magnetosphere., the plasma on the flux tube will sense an electric field $E = U_{sw} \times B_{sw}$, where $U_{sw}$ is the flow velocity of solar wind and $B_{sw}$ is the magnetic field of solar wind. In a steady state, (**Hundhausen, A.J.and Burkepile J.T.1994**)[8].The electric field must be sensed all along these now open flux tubes, as field lines are equipotentials. At the ionospheric end of the field line, this electric field, which is directed from down toward dusk, derives flow from noon towards midnight. The variation of the north-south component of IMF provides an opportunity to enter solar wind energy that is transferred into magnetosphere and others have described the relationship of $B_y$ component of the IMF to the configuration of the auroral oval, polar cap arcs and ionosphere convection pattern in both hemispheres of the Earth. The interplanetary magnetic field has a long southward component ($B_s \geq 10$ nT) the observed polarity of the field near the solar flare.

## Morphology of Geomagnetic Storms

The first includes relatively small and regular daily variation, and the second is the disturbances of a more violent nature known as geomagnetic storms. Alexander von Humboldt was the first to discover the dependency of magnetic intensity on latitude and observed the geomagnetic field at various locations at Earth. The variation in geomagnetic field is known as geomagnetic storm.**( . Paredes M.**

**B.1992)**[9].Geomagnetic storms are major disturbances on the magnetosphere that occur when the interplanetary magnetic field turns southward and remains southward for prolonged period of time. During a geomagnetic storm main phase, charged particles in the near-earth plasma sheet are energized and injected deeper into the inner magnetosphere, producing the storm-time ring current. During geomagnetic disturbances an electromagnetic flux ≈ $10^{11}$-$10^{12}$ W enters in the magnetosphere from the solar wind. According to current concepts, part of the energy flux is stored inside the magnetosphere at the distance of few Earth radii as energetic ions. **(Crooker,N.U.1994)**[10] .The ion motion around the geomagnetic dipole is accompanied by a decrease of the H-component of the geomagnetic field.The second part of the energy flux is used in generating 3D current system. The third part of the energy flux is stored in the tail of the magnetosphere as magnetic field energy geomagnetic activity indices are well correlated with the solar events and vary with 11-year sunspot cycle.

## Secular Change

The small and erratic secular changes, also known as quiet time variations are apparently caused by motions within earth's interior. The principle source of the quiet time long period geomagnetic field variation is beneath the earth's surface. The studies of rock mechanism as well as geological time survey estimate the geomagnetic field directions over the past $5\times10^{8}$ years. These measurements have been indicated substantial changes and even reversals in field direction in the past. It has been well known that the total magnetic dipole moment has systematically decreased for more than a century.**( Kahler,S.W.1992.Annu)**[11].The changes in magnetic dipole moments can be expressed by a relation [M = (15.77 - 0.003951× t). $10^{25}$ Gauss-cm $^{-3}$] where **t** represents time in years reckoned forward or backward from 1900 AD. If this rate of decrease continues, the dipole magnetic moment would become zero at 3991 AD. The geomagnetic secular change in total intensity during only a single decade is noteworthy. The average changes per annum in secular variations are ranging between 100-150nT.The average changes in decade becomes regionally important in semi-annual variation of geomagnetic field.The solar quiet variation (Sq) also known as diurnal variation is an important phenomenon to understand various types of geomagnetic activityhence its interpretation requires an understanding of the atmospheric dynamics.**(Bartels, J.1940)**[12].This feature indicates the central position of the current vortices. The current system which is responsible for the $S^{p}_{q}$ variation consist of an inward field-aligned current from the morning side of the magnetopause to the morning half of the auroral oval and an outward field-aligned current from the afternoon half of the oval to the afternoon side of the magnetopause, together with ionospheric currents across the polar cap.

## Geomagnetic Storms

The geomagnetic storms and auroras were caused by interactions of the solar corpuscular radiation and earth's magnetic field. Chapman and Bartels (1940) had recognized that over the major part of the Earth, the principal average feature of a magnetic storm is an unmistakable decrease of the horizontal intensity and its subsequent recovery.This decrease in intensity is caused by enhancement of the trapped magnetospheric particle population. A geomagnetic storm is a global disturbance of the earth's magnetic field and usually occurs in response to abnormal conditions in the interplanetary magnetic field and solar wind. The geomagnetic storm is a sequence of varying magnetospheric disturbances and varying conditions in interplanetary space,

## Standard Geomagnetic Storms

A standard geomagnetic storm is temporary disturbances in the earth's magnetosphere. Shock waves that may be associated with solar coronal mass ejections or coronal hole arrive 24 to 36 hours after occuring event.The propagation of hydromagnetic waves is complicated during the passage of the wave through ionospheric medium, which is very weakly ionized plasma. Finally, Main and recovery phase, whereas, gradual commencement storm having only main and recovery phase. Once the initial shock wave has passed the solar wind returns to normal pressure and the magnetosphere recovers. Over the next several hours, the magnetic field remains fairly stable with only minor fluctuations. **(Alan,H.1994)**[13].Some storms begin with the main phase that is usually caused by coronal holes that can eject solar materials without the violent explosions and fast solar transients.

## Initial, Main and Recovery Phases

The initial phase is magnetic manifestation of the interaction between post-shock solar wind and the magnetosphere. It is a quasi-steady state preceded sudden storm commencement. An enhancement in H-component is measured through ground magnetometer, during initial phase. This effect is unrelated to the ring current and is caused by an enhancement of the magnetopause current. In the low and moderate latitudes, horizontal component (H) rise several tens of nT within few minutes**(Baker, D.N. Payne, J. B.and Feldman, W. C.1981)**[14] .In the polar regions (above 80°dipole latitude) in the sunlit noon sector, a considerable increase in geomagnetic activity occurs after the sudden storm commencement. About three to six hours after the SSC, the main phase of the storm begins. At this time principally charge particles are lost from the ring current and the loss process occurs into several steps. First the rate of day-side reconnection decreases and the convection boundaries move to large radial disturbances. The low-energy ions that replace them contribute little current, and so the strength of the ring current decreases with time.**I**n that case the geomagnetic field remains disturbed for several days. After a few days,Several researchers have been shown various types result in this communication.Have shown that the sudden and gradual commencement storms are originated from two types of solar wind streams.Have shown that near solar activity maximum major geomagnetic storms tend to be preceded by sharp onset or 'sudden commencement type` and are predominately associated with transient disturbances in the solar wind arising from solar activity in magnetically closed regions.

# Conclusions

The geomagnetic cavity is also referred to as the magnetosphere, and the outer boundary of the cavity is known as magnetopause. Passing through the shock, which ranges in thickness varying from 100 km to 2 Earth radii, the solar wind is slowed, compressed, and heated. The low-altitude cusp is the dayside region in which the entry of magnetosheath plasma is directed at low altitudes. ( **Venkatesan,D.1994)[15].** Measurements have shown, that the cusp is highly confined region, A geomagnetic storm is a global disturbance of the earth's magnetic field and usually occurs in response to abnormal conditions in the interplanetary magnetic field and solar wind. The geomagnetic storm is a sequence of varying magnetospheric disturbances and varying conditions in interplanetary space, which are caused by coronal magnetic storms. During the geomagnetic storm, physically and geometrically disturbed geomagnetic fields D around the Earth have been studied by a number of researchers.Geomagnetic storm can be classified into many alternative ways on the basis of their distribution in space.

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