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"The Geomagnetic Field Variations Morphology of Geomagnetic Storms and Distribution of Plasma in the Magnetosphere"

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Abstract-:

There are two types of geomagnetic field variations termed as secular change and transient variations. The main field of the Earth is subject to a slow variation in time, known as secular variation. 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 (**Cane, H.V.1985**)[1].The variation in geomagnetic field is known as geomagnetic storm. The magnetosphere is filled with tenuous plasmas. Five plasma domains of different energy characteristics are well identified as the plasma mantle the plasma sheet the cusp region,

Introduction-:

The variation in geomagnetic field is known as geomagnetic storm. 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 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**)[2].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, after they are precipitated into the ionosphere by various plasma processes.Plasma particles in the upper and lower boundary layers of the plasma sheet are responsible for background luminosity in the pole-ward half the broad oval band.(**Akasofu,S.-I.and Chapman,S.Press,Oxford.1972**)[3] .The cusp regions are the two plasma regions of funnel-like structures in the dayside magnetosphere.The magnetosheath plasma can enter the magnetosphere through it.

The Open and Closed Magnetosphere-:

The open and closed magnetosphere shows the two states of the solar wind plasma 'frozen in magnetic field and the earth's magnetic field.In the closed model, interplanetary magnetic field direction are small and all field lines starting from the Earth and never cross the magnetopause or tail boundaries. In this model the magnetopause is a tangential discontinuity and the normal component of the magnetic field is identically zero. The concept of open magnetosphere model was firstly proposed by.This model indicates that the interplanetary magnetic field may reconnect with the dipole field along the sunlit side magnetopause.(**Baker,D.N.Payne,J.B.and Feldman,W.C.1981)**[4].The high latitude magnetic field lines, starting from the Earth, would be mingled with the interplanetary magnetic field and could be traced to the Sun.Such a field line may either penetrate the dayside magnetopause or be traced through the geomagnetic tail before finding itself in interplanetary space. Some researchers have been suggested three major sources of open magnetospheric models. First model explains all aspects of energetic solar particle entry in the polar cap when the characteristics of interplanetary particles are accounted for. Second model explains the open magnetosphere that provides a simple explanation of controlling of the magnetospheric current system by the interplanetary magnetic field and an explanation of all phases of the substorm. Third model express the open magnetosphere provides trivial explanation for the plasma pause,These plasma regions are well explained and sketched in **figure 1.** These plasma regions are all together called the plasma mantle.

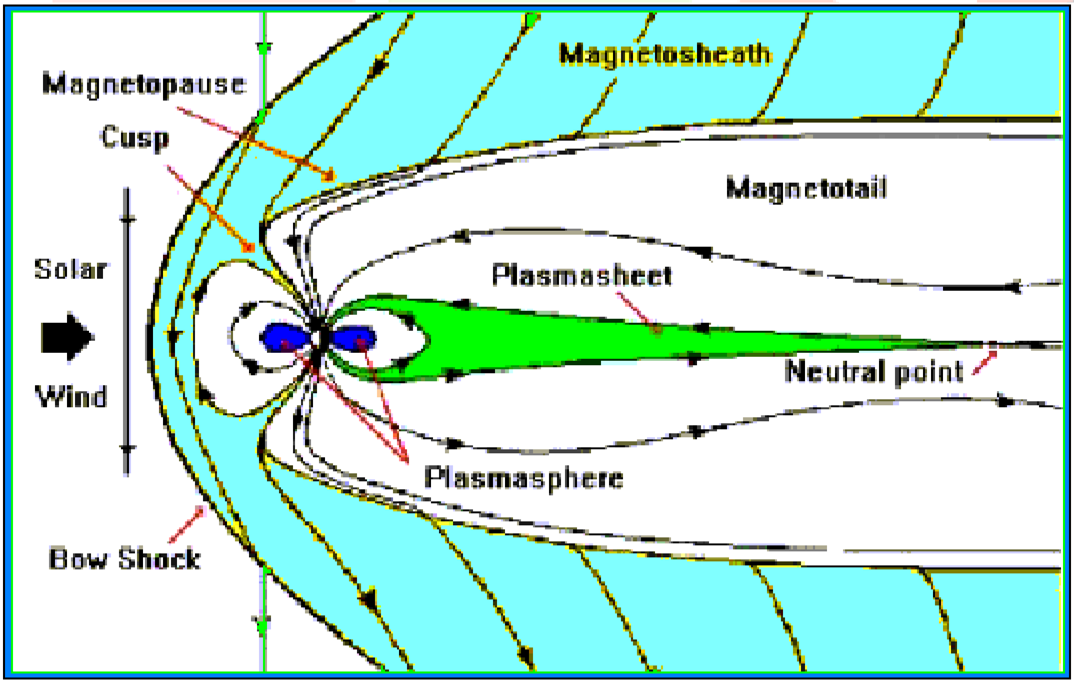

Figure 1. Shows the formation of the magnetosphere and its different regions such as bow shock, magnetopause, magnetosheath, magnetotail, cusp, plasma sheet, plasmasphere and neutral point.

We can use the open model of magnetosphere to estimate the length of the tail, as field lines are swept tailward in the solar wind; their ionospheric foot-prints are swept across the polar cap from near noon to midnight. (**Akasofu S.-I.1981)**[5] .Flow speed, time duration and foot of a field line cross the polar cap, can be measured from the ground. Those tail field lines that have disconnected from the Earth will retain tail geometry several thousand R_E beyond the Earth.

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(**Bartels,J.1940**)[6].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. When the IMF is directed predominantly southward, then the magnetic field driven by the solar wind flow against the front of the magnetosphere will be approximately antiparallel to the geomagnetic field on the other side of the magnetopause. The solar wind flow will pull the solar wind portion of the field line antisunwards, or, to pull it another way, 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, (**Gosling J.T. 1990**)[7].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 amount of transferred energy from solar wind to the magnetosphere becomes very large. On the other hand, the transferred energy becomes very small when the IMF directed primarily northward.Suggested that the polarity of the IMF at the Earth can be predicted from 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.**(Chapman,S. and Venkatesan,D.1963)**[8].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. This phase is characterized by the occurrence of multiple intense substorms, with the attendant auroral and geomagnetic effects. When the interplanetary field turns northward again, the rate of plasma energization and inward transport slows and the various loss processes that remove plasma from the ring current can begin to restore it to its pre-storm state. 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. **(Gosling, J.T.1993)**[9] .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. It is dissipated in creating 3D current systems and energetic particles, as well as plasmoid during substorm disturbances.Geomagnetic activity indices are well correlated with the solar events and vary with 11-year sunspot cycle. Geomagnetic activity is also modulated by the location of the Earth in its orbit around the Sun. The annual and semiannual variations can easily be seen in geomagnetic indices. The rotation of the Sun about its axis is also important for recurrent geomagnetic activities.

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 5×10^{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.**(Champbell,W.H.1996a)**[10].The changes in magnetic dipole moments can be expressed by a relation [$M = (15.77 - 0.003951\times t).\ 10^{25}$ 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 activity. On quiet days magnetospheric and ionospheric currents which are driven by energy input from the solar wind are either very weak or kept at fixed levels, and have a periodicity of one solar day. The Sq have been used to consider the dynamo action of the solar wind in the ionosphere, hence its interpretation requires an understanding of the atmospheric dynamics. The diurnal variation of geomagnetic field is measured through a number of geomagnetic observatories at mid and low latitude. In the Polar Regions there is an additional solar variation due to the current system S^{p}_{q}, show remarkable day-to-day changes of amplitude and phase. **(Bartels, J.1949)**[11].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, part of the wave descends through the basis of ionosphere and reaches the earth's surface resulting in the SSC. The SSC is characterized in low and moderate latitude by an increase in the horizontal component (H) of the geomagnetic field. A standard type of geomagnetic storm can be classified as: sudden commencement storm and gradual commencement storm. Sudden commencement storms consists initial, 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. It is not necessary that all geomagnetic storms begin with a sudden storm commencement (SSC). Fast solar eruptions and huge solar explosions mostly cause SSC impul. **(Gosling J.T.1996)**[12].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. **(Champbell W.H.1996b)**[13] .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, particles that have been ejected from the fast solar eruptions arrive at magnetosphere and produce ring currents. The main phase of geomagnetic storms generally lasts 12 to 24 hours and tends to be noisy. The main phase is the result of the superposition of a succession of explosive process, called magnetospheric substorm.Examined the topology of the earth's magnetic field for a very intense ring current belt and found that such a belt can reverse the direction of the earth's dipole field in a certain region.The third stage of a geomagnetic storm is the recovery phase. The recovery phase follows the active main phase. It consists of a slow quiet return of H field back to pre-storm level. After the main phase of the geomagnetic storms, when the IMF, turned northward, the ring current stops growing, and the ground perturbations begin to decrease. 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 ionosphere begins to fill flux tubes within the new boundary. As the cold ionospheric plasma encounters the ring current plasma, ion-cyclotron waves begin to grow, and these waves scatter the ring current proton into the loss cone. Other ring-current ions exchanged the charge with the cold neutral hydrogen. Ring-current ions become energetic neutral atoms and are lost to the atmosphere or outer space. The low-energy ions that replace them contribute little current, and so the strength of the ring current decreases with time. **(Farrugia, C.J.and Burlaga L.F.1997)**[14].This is the recovery phase of the storm. Sometime another storm take places before the effect of the first storm are wiped out, in that case the geomagnetic field remains disturbed for several days. After a few days, if there are no further large solar transients **Figure2.** Shows a well-developed standard type of geomagnetic storm consists: all initial, main and recovery phases of a geomagnetic storm.

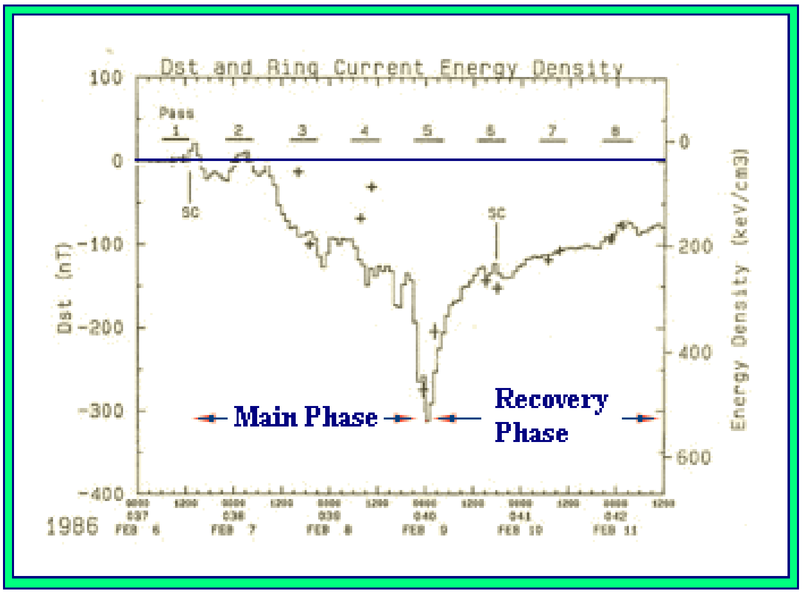

Figure 2. Shows a well-developed standard type of geomagnetic storm. The initial phase, main phase and recovery phase along with sudden commencement are also sketched in the figure.

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.Had recognized that the geomagnetic storms and auroras were caused by interactions of the solar corpuscular radiation and earth’s magnetic field.Had recognized that over the major part of the Earth.**(Hundhausen, A.J.and Burkepile J.T.1994)**[15] .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.

Conclusions-:

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, intensity, development in time and frequency of occurrence.**(Paredes M.B.1992)**[16].The geomagnetic storms have long been classified into two standard types, known as sudden gradual commencement storms depending upon different solar source activities.The importance of studying geomagnetic storms is basically two fold. One refers to their academic aspect of being considered a central part of geophysics. The magnetosheath plasma enters the magnetosphere in the form of a wedge and this perpendicular region is known as cleft.The cusp plasma is generally observed in the closed, rather than open field line regions. The energetic electrons in the cusp region have a pancake-like, pitch-angle distribution peaking at 90°. The solar electrons do not penetrate into the cusp region. The Van Allen belts which are the trapped regions of charge particles inside the magnetosphere can be classified as inner and outer belts. The presence of such a proton belt, together with the plasma sheet, causes a significant distortion of geomagnetic field.

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