COMPARATIVE STEADY OF EARTH'S MAGNETIC FIELD VARIABILITY, SQ-CURRENTS AND EQUATORIAL ELECTROJET OVER INDIAN, AFRICAN AND AMERICAN SECTORS

By

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The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "**COMPARATIVE STEADY OF Earth's magnetic field variability, Sq-currents and Equatorial electrojet OVER INDIAN, AFRICAN AND AMERICAN SECTORS**" by **Bogale Fentaye** in partial fulfillment of the requirements for the degree of **Master of Science in space physics**.

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Signature of Author

To My Family.

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Abstract

The earth's magnetic field during day and night is not the same due to different factors. The sun's radiation is one of the parameters to influence the variability of the earth's magnetic field in different sectors. The variation of magnetic field in turn produces huge variation in ionospheric currets such as the Sq- current, Equatorial Electrojet (EEJ), counter electrojets (CEJ). Equatorial electrojet (EEJ) is enhanced current flowing from west to east during day time at dip equator between $\pm 3^0$ latitude at an altitude of about 107 Km. This high concentration of electric current flowing from west to east in a narrow belt flanking the dip equator on the sunward hemisphere has been termed the equatorial electro jet. Our objective is to study , variation of the earth's magnetic field strength, Sq- current, EEJ and CEJ for African sector and American sector and the Indian sector. The magnetic field strength in the Indian sector is relatively stronger as the geomagnetic equator passes close to southern India, influencing EEJ intensity and variability. While in the African sector, the geomagnetic field is weaker compared to the Indian sector, resulting in higher ionospheric conductivity and often stronger EEJ current, When we come to the American sector the Geomagnetic field is relatively weakest but features a more significant magnetic declination (the angle between geographic and geomagnetic north), particularly in the south America. The declination impacts the electrodynamics, introducing additional east-west variability.

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Chapter 1

General interoduction

1.1 Introduction

Equatorial electro jet (EEJ) is an enhanced current flowing from west to east at an altitude of about 107km between $\pm 3^0$ geomagnetic latitude. EEJ is produced by the $E \times B$ drift and sun's radiation provides the unique medium for an intensified dynamo-generated atmospheric current system called solar quiet current(Sq) current. The EEJ shows magnifying the diurnal, seasonal, longitudinal and solar cycle variation. This high concentration of electric current flowing from west to east in a narrow belt flanking the dip equator on the sunward hemisphere has been termed the equatorial electrojet. The overhead current system has been found to be localized in latitudinal width to a narrow belt of about 600 km, at 75% peak value, centered at the dip equator, and at an altitude of about 100 km [1, 2, 3]. This current produced by electromotive forces is frequently considered to be due to the action of dynamo, which results in ground perturbation. The daily variations of the geomagnetic field when solar-terrestrial disturbances are absent are called solar quiet (Sq) variations [4]. Many other researchers studied the variations of the Sq, including [5] that examined seasonal variations and longitudinal inequalities of the electrostatic field in the ionosphere by looking at its electric conductivity and the Earth's main magnetic field. M. Takeda, [6] showed solar activity dependence of the Sq amplitude, and explained this effect through the ionospheric conductivity. He also compared the amplitude of the Sq for the same value of conductivity. According to him, the seasonal variation is seemingly due to differences in neutral winds or to the magnetic effect of the field-aligned current (FAC) flowing between the two Hemispheres generated by the asymmetry in the dynamo action. The FACs are controlled by interplanetary magnetic fields (IMF) and its electric fields can directly penetrate to the equatorial ionosphere [7]. The total variation measured on the ground consists both of external (ionospheric current) and internal (induced Earth current) contributions [8]. The pattern of the conductivity of surfaces layers of the Earth will introduce a corresponding small scale pattern in to the distribution of the induced currents. At some stations, an accurate indication of the average induced current system is difficult to determine, consequently its effects can not be fully distinguished [9].In his review, he suggested that the interpretation of field variations at a particular observatory must be done carefully. Although the ionosphere current system may have a fairly simple world-wide pattern, the relatively small variation of the conductivity distribution of the Earth's surface will introduce a corresponding small variation into the distribution of the induced currents. However, the external origin contribution of the Sq field is about 2.5 times that of the internal origin [10, 11] used a network of ten electro-magnetic stations installed at African latitudes to study the variations of geomagnetic field intensities on quiet days. They observed nighttime variations in all the three geomagnetic elements which according to them suggest there is a night-time current in the West African dip equatorial latitudes. The pattern of variations they observed in H element, which peaks around noon, they said is seen to be due to the equatorial electro jet current. They also noticed a reverse current called the counter electro jet current on some days. In their study of geomagnetic field variations from some equatorial electro jet stations using ten MAGDAS stations, [12] show that there could be substantial day to day variability in the electro jet (EEJ) strength along the dip equator. According to them, variations of greater than 80 nT are found in pairs of stations on the same day with the analyses showing correlation between pairs of stations decreasing as a function of increasing distance between them. Their results confirm the presence of counter electro jet occurring mainly in the morning and evening hours with strengths of up to 30 nT in certain instances. They showed a longitudinal variability in the EEJ, with results according to them showing strongest EEJ current in the South American sector and weakest in the Malaysian sector. Abbas [13] examined magnetic records from 3 stations along the equatorial chain for solar quiet daily variations of the horizontal component of the Earth magnetic field. Their result shows there could be substantial day-to-day variability in the electro jet (EEJ) strength, with the EEJ appearing stronger in East than West. This according to them suggests that there could be a process of re injection of energy as jet flows eastward. They also noticed seasons of peak in H which differs in each station with Sq day-to-day variability having consistent and explicable diurnal and seasonal variation. They finally inferred that seasonal change in the Sq variation is explicable in terms of seasonal shift in the mean position of the Sq current system of the ionospheric electro jet, seasonal movement of electro jet current focal latitude and width, and the electrodynamics effects of local winds.

Klausner [14] used the horizontal component amplitudes of magnetometer recorded by ground-based observatories of the INTERMAGNET network to analysis the global pattern variance of the solar diurnal variations. Their results show that the magnetic records have a latitudinal dependence affected by the season of year and by the level of solar activity. They found a disparity on the latitudinal response at Southern and Northern Hemispheres during solstices, which are expected due to the asymmetry of the Sq field. On the other hand at equinoxes, records from stations located at approximately the same latitude but at different longitudes presented peculiar dissimilarities. The achieved results suggest that quiet day patterns and the physical processes involved in their formation are strongly affected by the conductivity of the E-region, the geomagnetic field intensity and its configuration and the thermosphere winds. The variations observed in the ground magnetic records on geomagnetic quiet days are found to be associated with the dynamo currents, which are driven by winds and thermal tidal motions in the E regions of the ionosphere [15]. It has been pointed out that the geomagnetic field intensities change significantly from place to place, from one day to the next, and also from hour to hour. Recent studies on the variability of the geomagnetic field intensity include the works of the authors of [16] studied the average latitudinal profile of dH , American zone [17]. Studies on the seasonal variations of dH have also been carried out, they include works [15, 18] It should be noted that, although much work has been done on the variations of geomagnetic field components, few results has been obtained in the equatorial African American region. This may be attributed to lack of magnetic observatories in the region. The significant of this work is as shown be

1.2 Statement of the problem

Although EEJ is an enhanced current during the day time its value is not the same along the longitude sector. So we would like to compare the EEJ, its counter electro jet [CEJ] and pre-reversal enhancement processes in the Indian, the African and American sectors of the ionosphere. This comparative study will help determine the best practices for implementing technologies in different geographical locations, leading to more accurate and reliable methods of in enhancing ionospheric conditions for improved signal propagation and mitigation.

1.3 Objectives

1.3.1 General Objectives

Comparative analysis of EEJ counter electro, jets and pre- reversal enhancements over the Indian, African and American sectors. The overarching goal is to enhance the understanding of equatorial ionospheric processes and their influence on the magnetosphere space weather ionospheric dynamics in different region

1.3.2 Specific Objectives

- To analysis the variation in the intensity of EEJ sq-current and strength of earth's magnetic field in the Indian, African and American sectors
- To investigate the spatial distribution of the EEJ currents sq-current and strength of earth's magnetic field in the three sectors using data from ground-based magnetometers data

- To examine the temporal evolution of EEJ currents sq-current and strength of earth's magnetic field in the three sectors using data from ground-based magneto meters
- To assess the impact of geographical factors, geomagnetic field variations and ionosphere conductivity differences on the behavior and characteristics of EEJ currents sq-current and strength of earth's magnetic field in the three sectors

1.4 The significant of the study

The purpose of this study is to:

1. carry out comparative study of EEJ currents sq-current and strength of earth's magnetic field in the three sectors using data from ground-based magneto meters.
2. Employ the solar quiet (Sq) ionospheric current variations with hourly values along the geomagnetic equatorial regions of African and American and Indian sector
3. to analyze the cause for maximum and minimum EEJ and sq-current
4. The ionospheric variation of sq current system is an important aspect for studying Conditions on the magnetosphere, ionosphere, and thermosphere and the currents in the ionosphere. Adverse conditions in the space environment can cause disruption of satellite operation, communication, navigation, and electric power grid and can lead to variety of socioeconomic losses. The associated discipline aims, through observation, monitoring, analysis and modeling,

at understanding and predicting the state of the sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them; and also at forecasting and now- casting the possible impacts on biological and technological systems.

5. to compare the amplitude variation of magnetic field component at daytime and night- time. And therefore the significance of the study the ionospheric variation of sq current system is an important aspect for studying electromagnetic wave propagations conducted a pilot study of the day-to-day variability of geomagnetic field variety. Solar-quiet (Sq)on the other hand is a global current system consists of two large vortices of electric currents in the dayside ionosphere, one in each hemisphere, counter-clockwise in the Northern hemisphere, and clockwise in the Southern hemisphere. This current is driven by solar EUV radiation, which is not only produces the ionization but also heats the atomsphere and causes the wind. Both current overlap at dip equator to give total current and greatly affect the geomagnetic data measured around there

Chapter 2

Review of related literature

2.1 Review of related literature

The Earth's Magnetosphere field and ionosphere Earth's magnetosphere is the region where the earth's magnetic field is detected. Basically this region is studied detailed in relation to the interaction of solar wind phenomena. The active regions on the Sun (then named M regions) emit continuously corpuscular radiation responsible on the Earth for the occurrence of recurrent geomagnetic storms with a period of 27 days. The geomagnetic storms with the emission from the Sun of clouds of ionized gas with speed of about 1000 km/s [19]. The acceleration of the CO+ clouds in the comet tails with continuous emission of plasma. One of the first evidences of solar wind, i.e. of a corpuscular outcome radially flowing away from the Sun, was provided by the studies on the comet tail shape. So the ionic tail reveals the existence of the solar wind.

2.1.1 Earth geomagnetic fields

The Earth's magnetic field is generated in the fluid outer core by a self-exciting dynamo process. Electrical currents flowing in the slowly moving molten iron generate the magnetic field. In addition to sources in the Earth's core the magnetic field observable at the Earth's surface has sources in the crust and in the ionosphere and magnetosphere. The intensities of this geomagnetic field vary on a range of scales. It varies from one location on the Earth surface to another, from one solar cycle to another, from month to month, day to day and even from hour to the next [20]. Of the three components of this field namely the external, the anomalous induced and the main magnetic fields, the main magnetic field accounts for large regional variations in intensity and direction. This variation is easiest to observe during periods of low solar activity when large irregular disturbances are less frequent. For this reason it is often referred to as the solar quiet or Sq variation. Owing to the continuous time scale variation of the field, the amount of magnetization of rock materials is dependent on the changes of this field. This field arising from magnetic materials in the Earth's crust varies on all spatial scales and is often referred to as the anomaly field. Knowledge of the crustal magnetic field is often very valuable as a geophysical exploration tool. This is because rocks and ores can become magnetized by induction in the geomagnetic field. Magnetic exploration involves mapping variations in the magnetic field to determine the location, size, depth and shape of deposits of such ores and consequently the local geology. The magnetic susceptibility of igneous rocks is generally much greater than sedimentary rocks. Consequently, the major magnetic anomalies observed in surveys of sedimentary basins usually result from the underlying basement rocks. Determining the depths of the tops of magnetic bodies is thus a way of estimating the thickness of the sediments. The Earth's magnetic field corresponds approximately to that of a dipole situated at the centre of the Earth with its axis inclined at an angle of about 11^0 to the axis of rotation Fig. (2.1).

There are, appreciable temporal and spatial departures from this simple model. According to presently accepted theories, the smooth geomagnetic or 'normal' field and its slow secular change are ascribed to fluid motions in the Earth's electrically conducting core. The influence of magnetic constituents of crustal rocks superposes on the normal field anomalies whose magnitude can, in extreme cases, be comparable to that of the normal field. In addition, changes on the Sun and of its position relative to the Earth cause erratic and often rapid fluctuations in the magnetic field (magnetic storms) occasionally exceeding one-tenth of the normal field value, as well as smaller and more regular diurnal and seasonal variations. The Earth has a large and complicated geomagnetic field. The geomagnetic field one can measure at the Earth's surface or on board satellites is the sum of contributions from many different sources. These sources have different physical origins and can be found both below (in the form of electrical currents and magnetized material) and above (only in the form of electrical currents) the Earth's surface. Each source happens to produce a contribution with rather specific spatial temporal properties. The major part of the field is produced by a self-sustaining dynamo operating in the fluid outer core as already stated. What is measured at or near the surface of the Earth, however, is the superposition of the core field and of additional fields caused by magnetized rocks in the Earth's crust, by electric currents flowing in the ionosphere, magnetosphere, and oceans, and by currents induced in the Earth by the time-varying external fields. The sophisticated separation of these various fields and the accurate determination of their spatial and temporal structure based on magnetic field observations is a significant challenge, which requires advanced modeling techniques [21] which rely on a number of mathematical properties

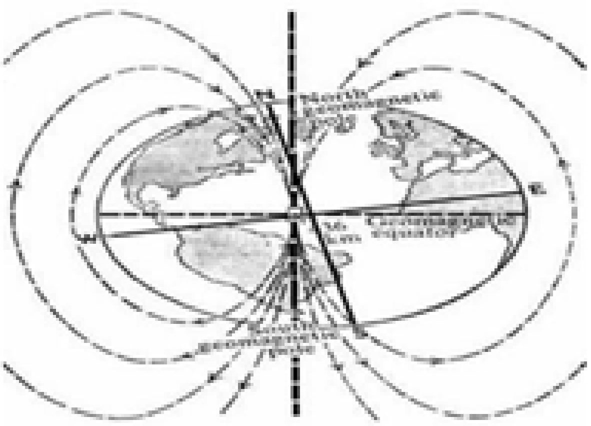

Figure 2.1: The Earth Geomagnetic Field

Several sources contribute to the magnetic field that is measured at or above the surface; Fig. (2.2) shows the inner core, the outer core, the mantle and the crust are the four layers of the earth and the field is due to electrical currents in the Earth's fluid outer core at depths larger than 2,900 km; this is the so called core field. Its strength at the Earth's surface varies from less than 30,000 nT near the equator to about 60,000 nT near the poles, which makes the core field responsible for more than 95% of the observed field at ground [22]. Magnetized materials in the crust cause the crustal field; it is relatively weak and accounts on average only for a few percent of the observed field at ground. Core and crustal fields together make the internal field (since their sources are internal to the Earth's surface).

External magnetic field contributions are caused by electric currents in the ionosphere (at altitudes 90-1000 km) and magnetosphere (at altitudes of several Earth radii). On average their contribution is also relatively weak- a few percent of the total field at ground during geomagnetic quiet conditions. However, if not properly

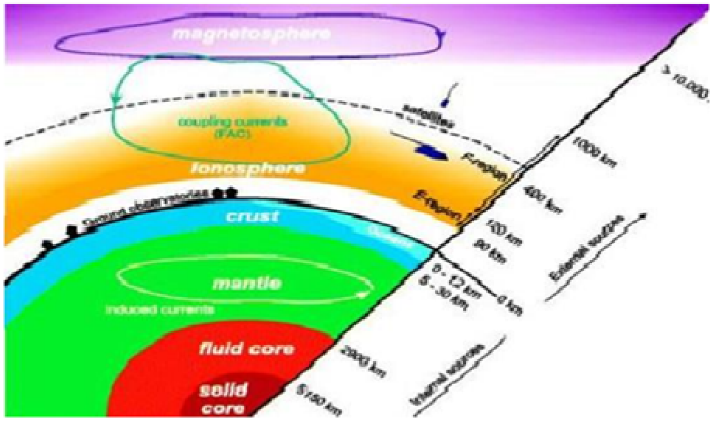

Figure 2.2: Various sources contributing to the near-Earth magnetic field

considered, they disturb the precise determination of the internal field. It is therefore of crucial importance to account for external field (by data selection, data correction, and/or field co-estimation) in order to obtain reliable models of the internal fields. Finally, electric currents induced in the Earth's crust and mantle by the time-varying fields of external origin, and the movement of electrically conducting seawater, cause magnetic field contributions that are of internal origin like the core and crustal field; however, typically only core and crustal field is meant when speaking about "internal

2.1.2 The External geomagnetic Field

The external field is the portion of the geomagnetic field that results due to the existence of currents in the upper atmosphere due to the movement of conductive air across the lines of force of the earths magnetic field, caused by solar heating. However even at the surface and at low altitudes, where the contribution of the external field is a very small percentage, As the strength of the internal field weakens with increasing distance from the earth, the external field becomes relatively more important. The geomagnetic field on the ground shows regular variation with a fundamental period of 24 h during a solar quiet day. This regular variation depends on the local time, latitude, season, and solar cycle, and it is known as the solar quiet (Sq) geomagnetic field daily variation (e.g [8, 23, 24, 25, 26, 27]) . The regular variations are due to the apparent movements of the Sun and Earth. However, the lunar and solar cycles do affect in a more or less regularized manner with maximum TEC during high solar activity period which gradually decreases towards the low solar activity periods. Its effect is noticed from the variations with abnormally large amplitudes in the horizontal components of the magnetic field. The Study of Chapman [28] has suggested that the intense current flowing eastward in a narrow band along dip equator is known as electro jet. Since, there have been many studies investigating the EEJ from ground based geomagnetic observations [29] and from rockets [30].

2.1.3 The geomagnetic field Elements

Geomagnetic elements are vector components used to describe the geomagnetic force field at any point on the Earth surface. According to most recent theories, the geomagnetic field is generated by electrical currents in the liquid outer core. This field is considered to be in a positive direction if an isolated magnetic pole would freely move in that direction. By international agreement, a set of names and symbols is used to describe the Earth's field components in a "right hand system". Generally there are seven components of the Earth's magnetic field namely X, Y, Z, H, F, I and D.

Figure 2.3illustrates this nomenclature for a location in the Northern Hemisphere

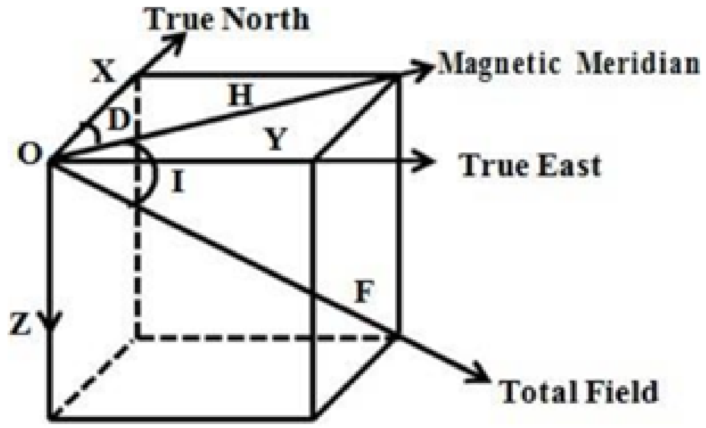

Figure 2.3: Components of Geomagnetic Field

where the total field vector points into the Earth. The geomagnetic field at any point is usually defined by three of seven elements: five intensity components and two angles. Observers however, prefer to describe a vector representing the Earth's field in one or two ways: (1) three orthogonal component field directions with positive values for geographic northward, eastward, and vertical into the Earth (negative values for the opposite directions) or (2) the horizontal magnitude, the eastward (negative for westward) angular direction of the horizontal component from geographic northward, and the downward (vertical) component. The first set is typically called the X, Y, Z component representation while the last is called H, D, Z component representation. X is the magnetic component lying in the geographic meridian being considered positive and negative in the horizontal north and south direction respectively. Y is the magnetic component lying perpendicular to geographic meridian and is positive and negative in the horizontal geographic east and west direction respectively. Z is the vertical magnetic intensity which lies vertically downwards being positive in this direction and negative in the vertical upward direction. F is total magnetic field intensity. H is the horizontal magnetic intensity which lies in the geomagnetic plane and is positive in all directions. D, the angle of declination is the angle between the magnetic meridian and the north geographic meridian. It is positive northwards from geographic meridian to the magnetic meridian and negative horizontally in the reverse direction. I, the angle of inclination or dip angle is the angle between the total magnetic field strength and the horizontal intensity. It is positive if it points downwards and negative if inclined upwards. The components X, Y, Z, H and F are measured in Nano Tesla while D and I are angular measurements expressed in degrees and minutes of arc the relationship between the magnetic elements. The Declination (D),Inclination (I) and Horizontal (H) areas follows.

$$D = \tan^{(-1)}(\frac{Y}{X}) \tag{2.1.1}$$

$$I = \tan^{(-1)}(\frac{Z}{H}) \tag{2.1.2}$$

$$H = \sqrt{X^2 + Y^2} \tag{2.1.3}$$

The total field is

$$F = \sqrt{X^2 + Y^2 + Z^2} \tag{2.1.4}$$

The strength of the Earth's field is measured at numerous magnetic observations located all over the world in either X, Y and Z or H, D and Z rectangular components. The International System of Units (SI) unit of magnetic field intensity, strictly flux density, most commonly used in geomagnetism is the Tesla. At Earth's surface the total intensity varies from 24 000 nano tesla (nT) to 66 000 nT. Other units likely to be encountered are the Gauss (1 Gauss = 100 000 nT)

2.2 GEOMAGNETIC FIELD VARIATIONS

The ionospheric effect on a regular day is the integrated effect of geomagnetic field varies all these parameters. These are the diurnal variation: in sq current system is due to the regular rotation of the Earth about its own axis following the apparent movement of the Sun. However, the net diurnal change in the quiet day low latitude ionosphere mostly depend on the photo-ionization production and recombination losses associated with the local solar radiation and the field-aligned diffusion of the transported electrons from the equator. Secondly, day-to-day variability of the Sq current on one day is different from Sq of another day even at the same hour in amplitude and phase. This implies that, there is day-to-day variability in the ionospheric conditions in the region of interest, i.e. low latitude. Thirdly, seasonal variations of geomagnetic field also is observed due to the tilt and rotation of the earth around the Sun. The relative position of the Sun moves from one hemisphere to the other with seasonal variation of solar zenith angle and intensity of radiation at any geographical location. Usually, the whole year is categorized into four seasons, i.e., December solstice (November, December and January), March equinox (February, March, and April), June solstice (May, June, and July) and September equinox (August, September, and October). Onwumechili [29] Noted that the seasonal variability could be partially explained by the seasonal variation of lunar semi-diurnal tide. Seasonal change in the Sq variation is attributed to a seasonal shift in the mean position of the Sq current system of the ionosphere electro jet [30]. The Geomagnetic filled also shows latitudinal variation: a place's latitudinal location affects the amount of incoming solar radiation the place receives, and there its temperature. Much of the Africa (nearly 2/3 rd) lies within the tropical latitudes. Hence, the continent receives high sun angles throughout the year. as latitude increases from the equator towards the north and south direction, the solar radiation strikes the atmosphere more obliquely. Hence, the intensity of radiation and production of free electrons decrease with increasing latitude. Near the geomagnetic equator, the geomagnetic field is horizontal, and the electric field is eastward during the day and westward at night due to dynamic effect by atmospheric motion. The E-region electric field is mapped into F-layer through the $(E \times B)$ drift of plasma which then diffuses along the slope of magnetic field lines at approximately 15^0 geomagnetic latitudes forming crests on both the hemispheres equatorial ionosphere anomaly region (EIA). At any world location, the geomagnetic field is not constant in time [22]. The daily record of geomagnetic variations at any world location typically shows a multitude of irregular changes in the geomagnetic field that represents generally increases with Unique current sources in the upper atmosphere and magnetosphere have been identified as the origins of many of these spectral field variations some are listed below

2.2.1 The earth magnetic field variation

The presence of electric currents flowing above the earth's surface, the magnetic field at any point on the surface varies diurnally, seasonally, and with solar activity. The net variation at the earth's surface is due partly to the external currents and partly to induced earth currents. Days on which the transient magnetic variations are smooth and regular are called magnetically solar quiet days(Sq). The others, magnetically disturbed days, are said to be magnetically disturbed Sd. On Sq days the magnetic variations proceed mainly according to local solar time, but they also contain a part, usually small, controlled by the noon. These two parts are called the solar daily and the lunar daily magnetic variation [28]. The regular variations are due to the apparent movements of the Sun and Earth. However, the lunar and solar cycles do affect in a more or less regularized manner with maximum TEC [total electron counter] during high solar activity period which gradually decreases towards the low solar activity periods. Its effect is noticed from the variations with abnormally large amplitudes in the horizontal components of the magnetic field. The Study by has suggested that the intense current flowing eastward in a narrow band along dip equator is known as electro jet. Since, there have been many studies investigating the EEJ from ground based geomagnetic observations [25].

2.2.2 Geomagnetic Temporal Variations

Interaction of the solar wind with the Earth's ionosphere and magnetosphere produces a variety of geomagnetic field variations with periods ranging from a few seconds to a few hundreds of years. Such naturally produced time-varying magnetic field recorded at the Earth's surface is a vector sum of its external and internal parts. The external (primary) part has its origin in the current systems generated in the ionosphere and the distant magnetosphere by the interaction of the solar wind with the Earth's permanent magnetic field. The internal (secondary) part arises due to the eddy currents induced in the conductive layers of the Earth by the diffusing external field within the Earth. Spherical harmonic analysis, SHA initiated by [31] showed that most of the geomagnetic field observed on the ground was of internal origin and only a small portion (about 1 percent) was of external origin. The main geomagnetic field, which is slowly varying, originates within the Earth. More rapid variations, with periods from seconds to days, are produced by processes above the Earth. At the top of the atmosphere, solar radiation creates an ionized region called the ionosphere. Above this is the magnetosphere where the Earth's magnetic field acts as a shield against the solar wind, the stream of charged particles coming from the Sun. Electric currents within the ionosphere and magnetosphere produce magnetic fields that are observed at the Earth's surface along with the Earth's own magnetic field. The sequences of phenomena that give rise to geomagnetic disturbances originate on the Sun. The simplest disturbance starts with the electromagnetic radiation given off by the Sun. As well as illuminating and heating the day-side of the Earth, this radiation also heats the ionosphere causing convection. The convection moves charged particles through the Earth's magnetic field creating a dynamo action that drives ionosphere electric currents above the equator and up to mid latitudes. These currents produce a magnetic field that, viewed from space, appears fixed on the day side of the Earth. The rotation of the Earth carries a site on the surface in and out of this magnetic field creating a 12-hour variation. Magnetic field on the surface of the Earth has been observed to change on timescales ranging from milliseconds to millions of years [32] also gave a wide spectrum of this variation covering periods of 10^{-5} seconds to 10^{15}seconds

2.2.3 Quiet Variation External Fields

The earth with its core, atmosphere, and main field rotates in the interplanetary environment and moves along its Orbit so that any point stationary in geographic coordinates experiences periodic variations in gravity force, solar illumination, and compression by solar wind effects. The field contributions that result from these motions vary diurnally and seasonally. Field contributions that vary this slowly and regularly and do not result from disturbances in the interplanetary environment are known as quiet variation fields .In the magnetic elements, of period about 24 hours, upon which more quiet daily variation refers to the magnetic variation on some days that are free from magnetic disturbances. During quiet times, the magnetic variations are primarily caused by the solar-quiet (Sq) and lunar (L) current systems. The two components of the regular daily variation, as observed on quiet days, are denoted Sq (Solar quiet) and Lq (Lunar quiet), for the solar and lunar influence respectively [4]. The magneto gram suggests that there may be a cyclic change irregular disturbances are superimposed. The amplitude of the regular variation was found to depend upon the magnetic latitude of the observatory: for observatories at the same Latitude, the variations were similar .This observation therefore indicated the sun used as a controlling factor. The two components of the regular daily variation, as observe

2.2.4 Secular variation

Secular variation refers to very slow changes with time of the geomagnetic field (declination, inclination, and intensity) that are probably due to the changing pattern of core flow. The term secular variation is commonly used for variations on time scales of 1 year and longer [8]. This means that there is some overlap with the temporal effects of the external field, but in general the variations in external field are much more rapid and much smaller in amplitude so that confusion is in fact, small. Cause of the secular variation: The slow variation of the field with time is most due to the reorganization of the lines of force in the core, and not to the creation or destruction of field lines. The variation of the strength and direction of the dipole field probably reflect oscillations in core flow. The westward drift has been attributed to either of differential rotation between core and the mantle or hydro magnetic wave motion: standing wave.

2.3 The Ionosphere of the Earth

A thick layer of air surrounding planets is called the atmosphere. This sea of air has density and exerts pressure. The atmosphere is comprised of layers based on temperature. These layers are the troposphere, stratosphere, mesosphere and thermosphere. A further region at about 600 km above the Earth's surface is called the exosphere. From this layer characterized by three maxima and two minima, together with the connecting layers of increasing or decreasing temperature in between. The first maximum arises from heating of the lowest air layers by the Earth's surface . The Encyclopedia Britannica (2007) defined the ions sphere as the part of the atmosphere that is ionized by solar radiation. This, in turn, receives most of its heat from the direct absorption of solar radiation. Additional heat comes from reabsorption of its own infrared radiation reflected primarily from atmospheric water vapor (greenhouse effect). Considered together, these effects produce a mean surface temperature of 288 K. Radiative cooling causes the atmospheric temperature to decrease with increasing distance from the warm surface of the Earth. The ionosphere is believed to be composed of six distinct regions: the C, D, E, and F regions, the heliosphere and the protosphere. However, the D, E and F regions are relatively distinct as the C region was considered to be the lower part of the D region. The heliosphere and the proton sphere are indistinct regions which are sometimes used to designate the regions of the ionosphere in which helium and hydrogen ions respectively are predominant and in which the atmosphere has thinned out to a near vacuum. The F layer was subsequently divided into regions F1 and F2. It is now known that all these layers are not particularly distinct and explains why scientists prefer the term ”region” to be more appropriate than ”layers” [23], but the original naming scheme persists

2.3.1 The D- Region

The D region is the lowest ionospheric region closest to the Earth surface, at altitudes of about 70 to 90 km (40 to 55 miles). The D region differs from the E and F regions in that its free electrons almost totally disappear during the night (except for the residual amount of ionization caused by cosmic rays), because they recombine with oxygen ions to form electrically neutral oxygen molecules. At this time, radio waves pass through to the strongly reflecting E and F layers above. The D region is very important though, because while it does not refract high frequency, HF radio waves, it does absorb or attenuate them. During the day some reflection can be obtained from the D region, but the strength of radio waves is reduced; this is the cause of the marked reduction in the range of radio transmissions in daytime. An example is the disappearance of distant amplitude modulation, AM broadcast band stations in the daytime. At its upper boundary the D region merges with the E region.

2.3.2 The E-Region

The E region is also called Kennelly-Heaviside layer, named for American electrical engineer Arthur E. Kennelly and English physicist Oliver Heaviside in 1902. It extends from an altitude of 90 km (60 miles) to about 160 km (100 miles). Unlike that of the D region, the ionization of the E region remains at night, though it is considerably diminished. The ionization density is typically 10^5 electrons per cubic centimeter during the day, though intermittent patches of stronger ionization are sometimes observed. Ionization in the E layer is primarily due to soft X-ray (1-10 nm) and far ultraviolet (UV) solar radiation ionization of molecular oxygen (O2). Normally, at oblique incidence, this layer can only reflect radio waves having frequencies lower than about 10 and may contribute a bit to absorption on frequencies above. The vertical structure of the E layer is primarily MHz determined by the competing effects of ionization and recombination.

2.3.3 The F- Region

The F region extends upward from an altitude of about 160 km (100 miles). This region has the greatest concentration of free electrons. Although its degree of ionization persists with little change through the night, there is a change in the ion distribution. During the day, two layers can be distinguished: a small layer known asF1 and above it a more highly ionized dominant layer called F2 . At night they merge at about the level of the F2 layer, which is also called the Appleton layer. Also at certain times during the solar cycle the F1 region may not be distinct from the F2 region with the two merging to form an F region. At night the D, E and F1 regions become very much depleted of free electrons, leaving only the F2 region available for communications. The lifetime of free electrons is greatest in the F2 region which is one reason why it is present at night. It is the densest point of the ionosphere, which implies signals penetrating this layer will escape into space. Because the F2 layer remains by day and night, it is responsible for most sky wave propagation of radio waves, facilitating high frequency (HF, or shortwave) radio communications over long distances. The F2 region is the most important region for HF radio propagation because: It is present 24 hours of the day, its high altitude allows the longest communication paths, and it reflects the highest frequencies in the HF range.

2.4 Ionosphere Dynamo Theory

Dynamo theory describes the process through which a rotating, convecting, and electrically conducting fluid acts to maintain its magnetic field. This theory is used to explain the presence of anomalously long-lived magnetic fields in astrophysical bodies. The conductive fluid in the geo-dynamo is liquid iron in the outer core, and in the solar dynamo is ionized gas at the tachocline. The ionospheric dynamo theory establishing relationship between the wind distribution in ionosphere and resulting system of fields and currents, deals with tide winds caused by gravitational forces and thermal effect of the Sun. In the upper atmosphere exists equal amount of positive ions and negative electrons embedded in neutral gases. The regular tidal wind system drives ionospheric plasma and pushes it against the geomagnetic field. Ions and electrons are affected differently by these winds. While the ions being massive still move essentially with the neutrals, the geomagnetic field already controls the motion of the electrons. The differential motion of ions and electrons is responsible for horizontally flowing electric currents. The name ”atmospheric dynamo” best describes those parts of the ionosphere where this current system is produced. Moreover, charge separation causes an electric polarization field, which is constrained by the condition of source free currents [32] and has been observed indirectly from backscatter measurements [26]. Lunar variations are usually less than 10% of magnitude of solar variation [11].

They depend not only on latitude, solar time, season and solar cycle, but also on lunar phase. Global analysis of geomagnetic lunar effects have also found significant longitudinal variations. The seasonal variations of the lunar magnetic perturbation tend to be greater than those for the solar perturbation. The lunar current system finds its origin in the ionosphere dynamo and lies close to the dynamo height along with Solar quiet (Sq) current system. The dynamo electric field associated with the wind drives a current, which tends to converge in some regions of space and cause an accumulation of positive charge, while in other regions of space it would diverge and cause negative charge to accumulate. These charges would create an electric field, which would cause current to flow tending to drain the charges. An equilibrium state would be attained when the electric-field driven current drained charge at precisely the rate it was being accumulated by the wind driven current. A net current flows in the ionosphere owing to the combined action of the wind and electric field [31]. Records of magnetic field as a function of altitude have been obtained from total-field magnetometers mounted in two Aerobes sounding rockets which were fired from the seaplane tender USS Norton Sound in March 1949. Results established experimentally the existence of a current system in the E-region of the ionosphere which is responsible for the diurnal variation of the Earth's magnetic field at sea level; and lend strong support to the dynamo theory of the daily magnetic variation which was originally proposed by [33]. Currents and electric fields produced by the ionosphere wind dynamo are relatively weak in comparison with those of the solar wind (magneto aspheric dynamo) at high latitudes. Electric field in the equatorial lower ionosphere has a localized strong enhancement of the vertical component associated with the strong anisotropy of the conductivity in the dynamo region. This enhanced electric field drives an eastward daytime current along the magnetic equator called equatorial electro jet [29] and [26] Dynamo potential differences may increase during the geomagnetic storms period due to the enhanced E and F region winds. Geomagnetic disturbed ionosphere wind dynamo can produce potential differences comparable to those produced by the quiet time dynamo (10 kV), with higher potential at the equatorial than at high latitude [34].

Chapter 3

Equatorial Electrojet(EEJ)

3.1 Equatorial electrojet (EEJ)

EEJ is an enhance current flowing from west to east during day time at an altitude of 107 Km between latitude of $\pm 3^0$ Geomagnetic latitude. At the geomagnetic dip-equator, the orthogonally crossed eastward electric field and northward geomagnetic field combine with the differential motions between ions and electrons in the E-region of ionosphere, to produce a strong vertical polarization electric field. This electric field associates with the northward geomagnetic field to increase the east-west electrical conductivity along the geomagnetic dip-equator in a narrow latitude band of $\pm 3^0$ geomagnetic latitude [35]. This process setup an intense eastward current, known as "equatorial electro jet" [28]. The E region Sq-current (solar quiet current) system is caused by the global solar-driven wind flowing across the magnetic field lines, resulting in an intensified eastward electric field in the dayside ionosphere. At the magnetic equator within where the geomagnetic field is nearly horizontal, the Sq current systems of the southern and northern hemispheres merge and intensify to

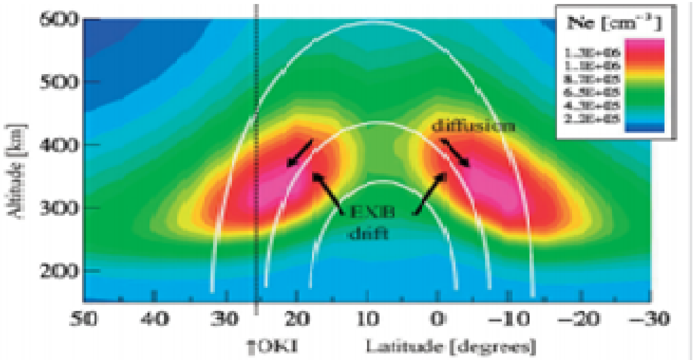

Figure 3.1:

form a jet-like current in the E-region of the ionosphere, which is called the "equatorial electrojet". The formation of the night-time plasma irregularity in the low and equatorial regions depends on the strength of the pre-reversal enhancement (PRE) and the angle between the day-night terminator and the northward Earth's magnetic field. When PRE is strong in magnitude, the equatorial upward $E \times B$ plasma drift will be strong during PRE hour and so that highly dense plasma will be lifted to a very high altitude where recombination reaction is very less. Therefore highly dense plasma lies on top of very less dense plasma and this creates suitable condition for the growth of less dense plasma in bubble form into highly dense plasma finally to form irregular plasma regions in the dense medium according to the Rayleigh-Taylor instability mechanism. Also when the angle between the day-night terminator and the northward Earth's magnetic field is parallel, during equinox season, the post-sunset $E \times B$ upward plasma drift gets its maximum value. This is because since the terminator and Earth's northward magnetic field are parallel during equinox season, the daytime eastward electric field E gets its maximum value around local sunset hours due to high conductivity gradient across the terminator. This electric field is

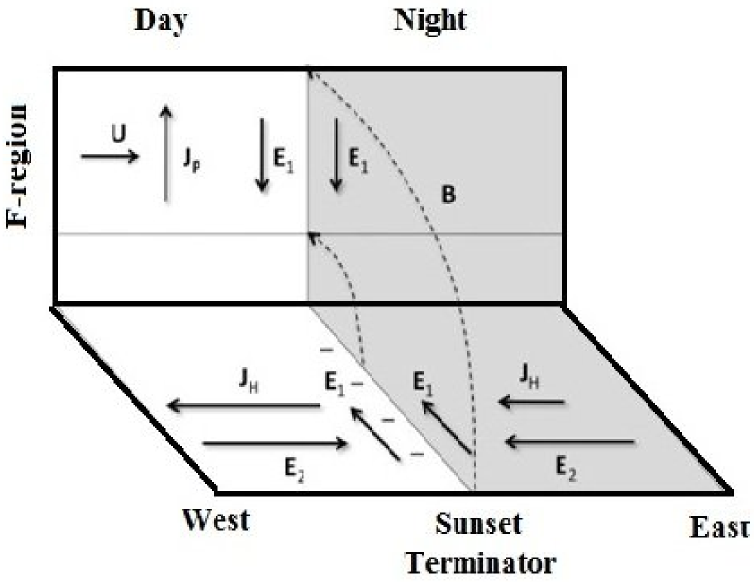

Figure 3.2: Simplified model of the F region Pre-reversal enhancement driven by Uniform F region wind U

perpendicular to the Earth's northward magnetic field so that the post-sunset $E \times B$ drift velocity gets its maximum value. Therefore the nighttime plasma irregularities that depend on the strength of the post-sunset $E \times B$ plasma drift velocity will be formed [36]. The conductivity that runs parallel to electric field E is known as the Pedersen conductivity. The Hall conductivity is the conductivity perpendicular to both geomagnetic field B_0 and E. Joule heating results from the flow of Pedersen currents, which also causes Ohmic losses. The element parallel to Bo continues to rise with altitude. A west-east oriented electric field around the geomagnetic dip equator produces vertical Hall currents that cannot close resulting in the electric field around the magnetic equator towards the east. The currents of Pedersen and Hall move to the east and downward, respectively, as a result of the crossing fields between northern magnetic and electric fields [37]. In relation to the high Pedersen conductivity, the Pedersen current flows dominantly at about 107 Km altitude. Figure below shows how these conductivities are formed at the geomagnetic equator. Basic equations from the Fig below schematically summarizes in as follows. In the processes that lead to the equatorial electro jet current flow In the dynamo region of the ionosphere near the dip-equator, the horizontal northward geomagnetic field B and zonal electric field E_y, produce an eastward Pedersen current $\vec{J}_{p1}$ (Eq. 3.1.1), and a vertical downward Hall current $\vec{J}_{H1}$ (Eq. 3.1.2) associated with electrons upward vertical $E \times B$ drift.

$$J_{p1} = \sigma_p E_y \tag{3.1.1}$$

$$\vec{J}_{H1} = -\sigma_{H1}(\frac{\vec{E} \times \vec{B}}{B}) \tag{3.1.2}$$

σ_p and σ_H are Pedersen and Hall conductivities respectively

On one hand, as ions $E \times B$ drift is impeded in the E-region due to collisions with neutral particles while electrons are relatively free to move, the resulting charge separation gives rise to an upward vertical polarization electric field E_p. On the other hand, E_p gives rise to an upward vertical Pedersen current J_{p2} (Eq.3.1.3):

$$\vec{J_{p2}} = \sigma_p E_P \tag{3.1.3}$$

And the $E_p \times B$ westward electron drift gives rise to an intense eastward Hall current J_{H2} (Eq. 3.1.4):

$$\vec{J}_{H2} = -\sigma_H(\frac{\vec{E}_p \times \vec{B}}{B}) \tag{3.1.4}$$

When the polarization process is complete, the upward vertical Pedersen current J_{p2} counter-balances the downward Hall current J_{H1} (Fig. 3.3), then the net vertical current becomes zero (Eqs.3.1.5) :

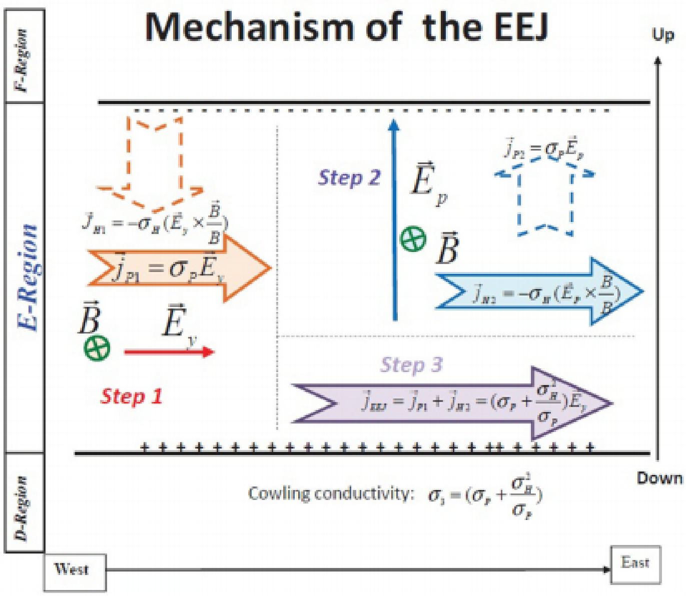

Figure 3.3: Mechanism of the equatorial electro jet current flow in the E region

$$\vec{J}_z = \vec{J}_{H1} + \vec{J}_{p2} = 0 \tag{3.1.5}$$

$$\vec{J}_z = \sigma_p E_P - \sigma_H(\frac{\vec{E}_p \times \vec{B}}{B}) \tag{3.1.6}$$

Fig.3.3Mechanism of the equatorial electro jet current flow in the E region is described in three steps. Step1: zonal electric E_y (red arrow), magnetic field B (green cross-circle), down ward Hall current density (dashed wide arrow) and the east ward Pedersen current (solid wide arrow). Step2: vertical polarization electric E_p (blue arrow), magnetic field B (green cross-circle), upward Pedersen current density (dashed wide blue arrow) and the eastward Hall current density (solid wide blue arrow). Step3: The total EEJ current density (wide pink arrow). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

And the west ward electron drift gives rise to an intense eastward Hall current

(Eq. 3.1.4): Step 3: When the polarization process is complete, the upward vertical Pedersen current counter-balances the downward Hall current EEJ contribution σ_H in the daily variations of the geomagnetic field horizontal component (H). However, most parameters of the equatorial electrodynamics cannot be reliably estimated from magnetic data alone. Among these parameters, the zonal electric field E_y, the vertical polarization electric field (E_p), the eastward Pedersen J_{p1} and Hall current J_{H2} densities and the net eastward EEJ current density can be mentioned. At the dip-equator, the zonal electric field and the northward geomagnetic field combine to produce the F-region plasma vertical drift. The zonal electric field can be approximately estimated if the F-region plasma vertical drift velocity and the geomagnetic main field intensity are known. While the geomagnetic field intensity can be easily estimated at any location through accurate models like IGRF, the F-region plasma vertical drift velocity, on the contrary, is harder to get everywhere. In fact satellite measurements provided the global view of equatorial F-region plasma drifts and associated electric field [38]. Those measurements depicted the longitudinal, seasonal and solar cycle effects. In addition, regional climatology models of the equatorial F-region plasma drift velocity were developed in the Peruvian, Brazilian and Indian longitude sectors [38]. Reported as well on operation near the dip-equator,

Chapter 4

Data and Methodology

4.1 Data source

The data source is obtained from the magnetometers deployed across the geomagnetic dip-equator, between $\pm 3^0$ dip-latitudes where the magnetometer networks is located with their geographic and geomagnetic coordinates of the stations are given in Table 1.

No	Station name	Station codes	Geog Lat	Geog Lon	Geom Lat	Geom Lon
1	Addis Ababa	AAB	9^0N	39^0E	0.17^0N	110^0E
2	Tirunelveli	TIR	8.48^0 N	76.95^0E	0.08^0N	$150.4^0 E$
3	Ancon	ANC	-11.77^0	282.85^0	3.05^0	354.4^0
3	Ilorin	ILR	8.5^0 N	4.6^0E	-1.82^0S	76.8^0
3	ABijan	ABJ	5.35^0	356.92^0	-3.53^0	-4.31^0
3	YAB	YAB	$9.49^0 N$	$138.08^0 E$	0.59^0N	208.73^0 E

4.2 Methods of Data Analysis

The analysis of this work passed through several processes. The selection of days , months and years under magnetically quiet days. The data used are minute data of magnetometers collected from different stations which we converted into hourly values (24 Hours). The resultant magnetic field is calculated from the three components (X,Y,Z) or (H,I,D)for the given stations in each sector, then the hourly values are plotted against time. We also plotted dH against time in each sector. Thus dH, give the measure of the hourly amplitude of the sq current. To calculate the EEJ we used two station one located at the equator and second at off equator. The mean of the hourly values H_0 is calculated for each data and taken as the base line.

$$\frac{H_0 = H_1 + H_{24}}{2} \tag{4.2.1}$$

The hourly sq current is given by

$$dH(t) = Ht = H_i - H_0 \tag{4.2.2}$$

where t =1,2...... 24. The monthly mean values of month was derived from the mean of the diurnal variations for month. since dH over the equatorial region is expected to reach its peak value at about local noon as a result of increase in ionization by solar activity in accordant with atmospheric dynamo theory [39, 31]. One of the data types that has been used for this study is the H- component of the earth.s magnetic field data collected from the magnetometers from which the EEJ has been obtained. For EEJ estimation the methods developed [40]and the references therein have been applied using data from two magnetometers deployed at magnetic equator and off equators for the three sectors. the value of dH(t) corresponds to Sq current at every hour and then The EEJ can be estimated from the difference of Sq currents obtained at the dip equator and off equator stations.

$$EEJ = Sq_{eq} - Sq_{off} \tag{4.2.3}$$

Chapter 5

Results and Discussion

In this chapter, we present plots of earths magnetic field for different sectors. The results show variations due to the ionization process showing ionospheric current systems in the African , Indian and American sectors. We also presented the dH, component of Earth magnetic field along the magnetic equatorial regions in the three sectors. In addition to this from the sq-current variability we examine the EEJ in the three regions. The results revel there is a difference in magnitude diurnally, seasonally and solar cycle variations due to different factors.

5.1 Magnetic field intensity variation

Figure(5.1) shows the hourly magnetic field intensity versus time is plotted for the three sectors. In all the stations the value of the Earth's magnetic field depends on time. As it can be seen from Figure(5.1) during night time ionosphere there is weak field and started monotonically to increase up to noon time then starts to decrease until mid night. However the magnitude is not the same for the three sectors. The

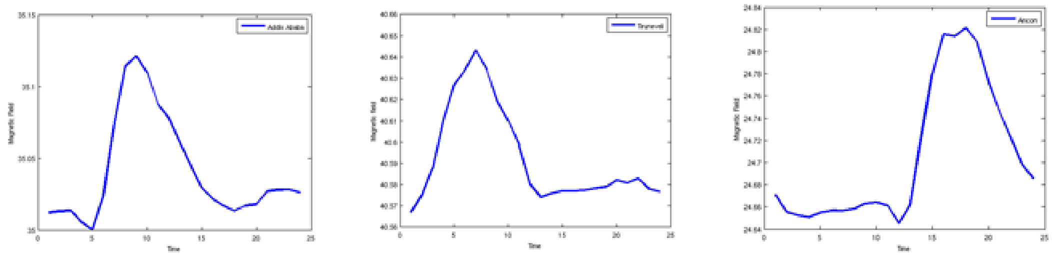

Figure 5.1: Magnetic field intensity in the African sector, Indian sector, and American sector from left to right respectively

geomagnetic field intensity over the American sector is found to be the weakest of all sectors followed moderate geomagnetic field over the African sector. But the Indian sector has registered the strongest geomagnetic field. From Figure(5.1) the Indian sector has strongest value of geomagnetic field intensity but varies significantly depending on seasonal and geomagnetic conditions. While the African sector shows higher variability influenced by its large extent, moderate geomagnetic field and diverse longitudinal conditions. However, in all sectors the trend is the same that is geomagnetic intensity to increase from morning hours and attains its peak value during noon time then starts to diminish afterwards.The Earth's dipole magnetic field is undoubtedly due to electric currents flowing deep within the Earth and the problem is to understand how the currents are generated and maintained. The observed diurnal variation in magnetic field is due to the ionization processes in the ionosphere led to the ionospheric currents. The geomagnetic field has a regular small variation with a fundamental period of 24 hours. Figure 5.1 shows graph of variation in the geomagnetic field at different stations.

5.2 Variability Sq-Current

The sq -current in the ionosphere is influenced by the tilt of the Earth's axis, the sun earth geometry, and the ionosphere conductivity. The Sq-current system arises from solar heating and tidal effects in the earth's atmosphere, leading to ionospheric winds that generate electric currents via the dynamo mechanism. This can be explained as follows: The Sq current forms large scale current loops in the E region of the ionosphere (altitude 90-150 km) and these loops are influenced by ionospheric conductivity that depends on solar radiation, neutral winds and geometry of the electric fields. This variability can be verified using figure (5.2). The currents reach peak value around local noon and very diminished during the night time for all sectors. The intensity varies with the solar zenith angle. The sun's position is not the same every month, this results variable intensity of light every month for the same hours. In general the tilt of the earth's axis leads to variations in the solar zenith angle across seasons. For example during the summer the sun is more directly overhead in the hemisphere experiencing summer resulting in higher ionospheric conductivity. On the other hand, the sun is at lower angle leading to reduced ionization and conductivity. This is clearly seen in figure (5.2) for the three sectors. So all the three sectors show seasonal, diurnal and solar cycle variation. However, the magnitude of Sq current in each sector in not the same for the same day or hour or season.

Other factor for variability are the dip angle between the magnetic field line and the horizontal plane. Near the equator, the magnetic field is nearly horizontal (low dip angle), enhancing the interaction of tidal winds with magneto-spheric plasma. At high altitude, however, the dip angle increases, influences the latitudinal structure and intensity of the Sq- current. The Sq-current also exhibits hemispheric asymmetry

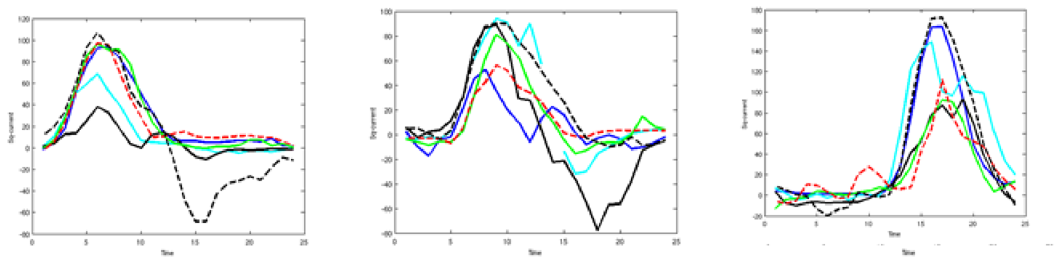

Figure 5.2: mass plot of Sq current for Indian sector, African sector and American secto respectively from left to right

due to the seasonal tilt. In summer stronger solar heating increases ionospheric winds and conductivity which leads enhancing sq current in the hemisphere. So in winter, these effects weaker, reducing the current strength. The mass plots in Figure(5.2) are plotted for the same station to explain if there is season dependence on Sq-current. It is observed that on solstices the Sq- current is diminished as compared to Equinox periods for all the three stations.

5.3 Estimated EEJ currents in the three sectors

Figure (5.3) shows diurnal variation of EEJ for some selected days. The days in the plots are selected as international quiet days from different stations depending on the data availability.

These plots were analyzed to study local time dependence of the EEJ for different regions along the geomagnetic equator. During the selected geomagnetic solar quiet days of the year the EEJ current sharply increase to their peak value from 9.00-13.00 LT, and gradually decrease and die out at around 18.00 LT which is in consistency with the dynamo action of the ionosphere which modifies the geomagnetic field. This phenomena is observed in all station found on the dip magnetic equator.

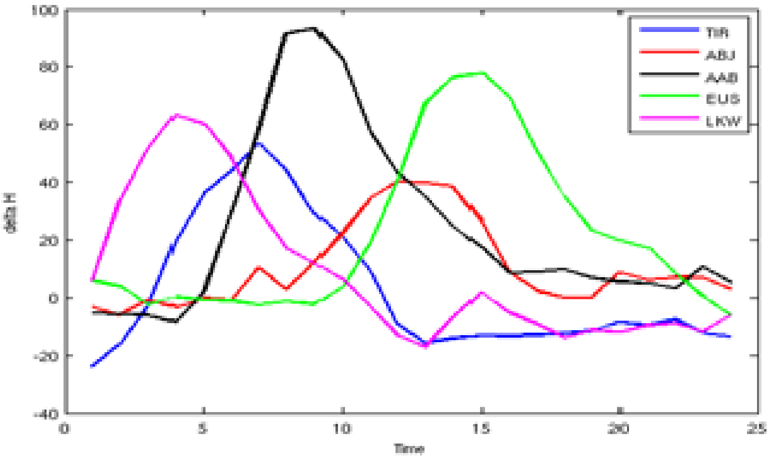

Figure 5.3: Diurnal variation of EEJ in different regions

5.4 Longitude dependence of EEJ

The EEJ intensity in the three sectors is also analyzed. From Figure(5.4) the Indian sector has moderate EEJ intensity but varies significantly depending on seasonal and geomagnetic conditions. While the African sector shows higher variability influenced by its large extent, weak geomagnetic field and diverse longitudinal conditions. However, in all sectors the trend is the same that is EEJ starts to increase from morning hours and attains its peak value during noon time then starts to diminish afterwards.

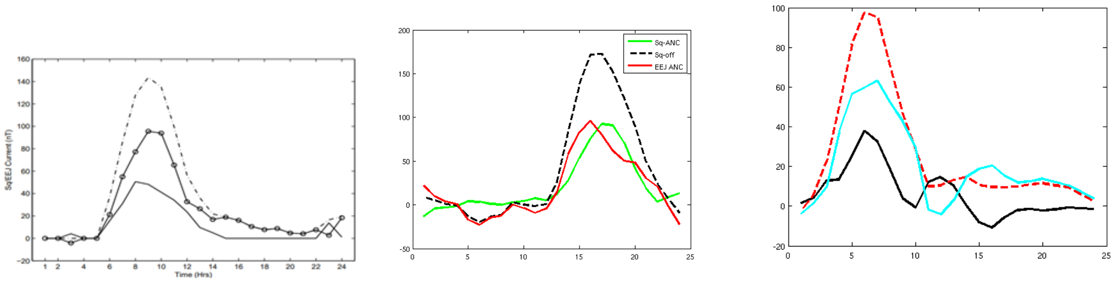

Figure 5.4: Diurnal variation of EEJ in different regions

5.5 Comparison of EEJ Indian African and American sectors

The equatorial Electrojet (EEJ) that exhibits distinct characteristics across the Indian, African and American sectors due to the differences in geomagnetic field strength, ionospheric conductivity and regional conductivities and regional electrodynamics. We examined the detailed comparison below. The magnetic field strength in the Indian sector is relatively stronger as the geomagnetic equator passes close to southern India, influencing EEJ intensity and variability. While in the African sector, the geomagnetic field is weaker compared to the Indian sector, resulting in higher ionospheric conductivity and often stronger EEJ current, When we come to the American sector the Geomagnetic field is relatively weak but features a more significant magnetic declination (the angle between geographic and geomagnetic north), particularly in the south America. The declination impacts the electrodynamics, introducing additional east-west variability.

Thus the EEJ intensity in the three sectors is shown below figure(5.4) the EEJ intensity is moderate but varies significantly depending on seasonal and geomagnetic conditions. The African sector however, displays the strongest EEJ intensity among the three. This is primarily due to the weaker geomagnetic field strength and favorite ionospheric conductivity. On the contrast the EEJ in the American sector is typically weaker than the African sector but stronger than the Indian sector. The large magnetic declination and regional plasma dynamics are the main candidates to weaker the EEJ intensity.The Occurrence of counter electrojets (CEJ) is more frequent in the African and Indian sectors. The CEJ is an enhanced west ward current which occurred usually during afternoon hours. The left and middle panels of figure 5.2 show negative values in the afternoon hours which is indicating a CEJ phenomena.

Feature	Indian sector	African sector	American sector
B strength	stronger	intermediate	weaker
EEJ	moderate	strongest	moderate
variability	high	highest	high
CEJ	frequent	frequent and stronger	less frequent
longitude dependence	moderate	strongest	strong
plasma instability	moderate	high	very high due to declination
Data availability	excellent	not good	excellent

The above table is a summary to explain the variation of the geomagnetic field strength, variation of the Sq current and Equatorial electrjet currents around the equatorial longitude circle by considering the Indian, African and American sectors as sample cases.

Chapter 6

Conclusion

The Magnetic field intensity, the Sq-current and EEJ diurnal and seasonal dependence are analyzed using geomagnetic field collected at different stations along the magnetic equator from magnetometers. The EEJ intensity in the three sectors is also analyzed. From Figure(5.4) the Indian sector has moderate EEJ intensity but varies significantly depending on seasonal and geomagnetic conditions. While the African sector shows higher variability influenced by its large extent, weak geomagnetic field and diverse longitudinal conditions. However, in all sectors the trend is the same that is EEJ starts to increase from morning hours and attains its peak value during noon time then starts to diminish afterwards. The EEJ intensity is moderate but varies significantly depending on seasonal and geomagnetic conditions. The African sector however, displays the strongest EEJ intensity among the three. This is primarily due to the weaker geomagnetic field strength and favorite ionospheric conductivity. On the contrast the EEJ in the American sector is typically the weakest compared to African sector and the Indian sector. The large magnetic declination and regional plasma dynamics are the main candidates to weaker the EEJ intensity. The equatorial

Electrojet (EEJ) that exhibits distinct characteristics across the Indian, African and American sectors due to the differences in geomagnetic field strength, ionospheric conductivity and regional conductivities and regional electrodynamics. We examined the detailed comparison below. Geomagnetic field Observation:- In the Indian sector, the magnetic field strength is relatively stronger as the geomagnetic equator passes close to southern India, influencing EEJ intensity and variability. While in the African sector, the geomagnetic field is weaker compared to the Indian sector, resulting in higher ionospheric conductivity and often stronger EEJ current, When we come to the American sector the Geomagnetic field is weak but features a more significant magnetic declination (the angle between geographic and geomagnetic north), particularly in the south America. The declination impacts the electrodynamics, introducing additional east-west variability.

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