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A REVIEW OF IONOSPHERIC LAYERS AND GEOMAGNETIC STORMS

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ABSTRACT: The Ionosphere region is a dynamic layer of outer atmosphere which shrinks and becomes larger in condition to solar conditions. Thus forms various layers in vertical direction i.e. D, E, F layers and varies differently in various latitudes. In this paper , we have reviewed the vertical dissection layers i.e. D, E, F layers in detail , consistent anomalies to the idealized behaviour of layers and geomagnetic storm of 2015 in Earth's ionosphere layer and studied the sequence of interplanetary and Earth's magnetic parameters during 15-20 March, 2015.

Keywords: Ionospheric layer, Geomagnetic storm, Ionosphere, D Layer, E Layer, F Layer, Equatorial electrojet, anomaly, perturbation.

INTRODUCTION

Ionosphere is the ample and spacious layer of electrons and ionized atoms and molecules in upper layer of atmosphere. This layer extends from 48km to 965km of altitude. Ionosphere includes thermosphere, parts of mesosphere and exosphere. This region is dynamic in nature which become larger and shrinks , depending upon the solar conditions. Ionosphere is an important link in the series of Sun and Earth interactions. This region is mainly responsible for radio communication on earth. Moving ahead this layer is divided into 3 categories namely D Layer, E Layer, F Layer .

The troposphere of atmosphere , the lowest part of atmosphere extends from the surface of earth to 10 km. Above Troposphere resides the stratosphere, followed by mesosphere. In the stratosphere, ozone layer is formed by the incoming solar radiation. In the thermosphere , the layer of the atmosphere is so delicately thin that the free electrons can only exist for a shorter period of the time. After a shorter period, the electron is captured by positive ion. The number of the free electrons present over here are adequate to influence the radio propagation. When the ionisation takes place in this region , it's is called partially ionized atmosphere , it contains a plasma which is referred to as the 'IONOSPHERE'.

Exploration of the region:

During the year 1839, it was postulated by the German physicist and mathematician Carl Friedrich Gauss that 'an electrically conducting region of the atmosphere could account for observed variation of earth's magnetic field'. About 60 years later, Guglielmo Marconi had received the first ever trans–Atlantic radio signal on December 12,1901, at St. John's, Newfoundland (now in Canada) by the antenna 156.4 m supported by kite and radio signal of power 100 times more powerful than ever produced in history. The message in encode text, Morse code of 3 dots for the letter of S. For reaching Newfoundland, the radio signal would have to reflect off the ionosphere twice. But after one year Marconi achieved trans-Atlantic wireless communication at Glace Bay, Nova Scotia.

Further in 1902, Oliver Heaviside proposed that a layer exists in ionosphere which he named as Kennelly-Heavyside layer. Heavyside layer extends from an altitude of 114 km to 250 km from the surface of earth. This year, scientist named Arthur Edwin Kennelly discovered some of the ionospheres' radio-electric related properties. For this, Kennelly got noble prize in 1947 after confirmation of existence of ionosphere in 1927.

In the early 1930's, test transmission of multilingual commercial broadcaster in Luxembourg called Radio Television Luxembourg inattentively or unintentionally provided evidence of the first radio modification of the ionosphere.

VARIOUS LAYERS OF IONISATION:

At the night, F layer of ionosphere is the one layer significant for ionization present; however the E and D layers are extremely low active for ionisation at night. During the day , the D and E layers are extremely ionized similar to F layer .Here the F layer forms an additional layer F_1 which is weaker region of ionisation. The F_2 layer continues to remain by day and night and it is the significant region responsible for the refraction and reflection of the radio waves.

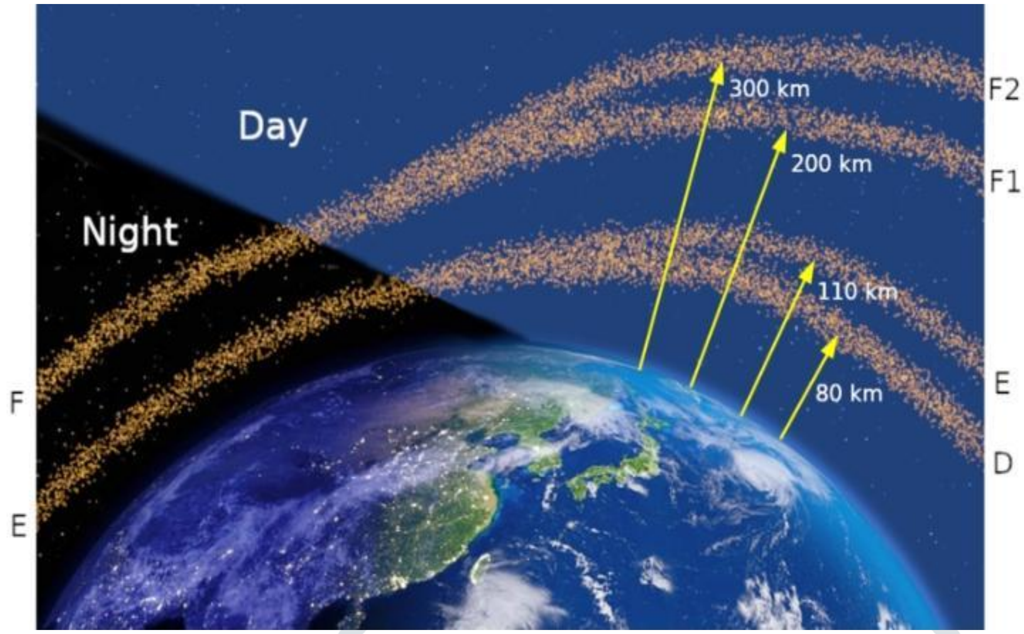

Figure 2: Image showing layers of ionosphere

D layer:

The D layer is the closest and innermost to the earth surface, at an altitude of 48 km and 90 km above the surface of earth. Ionisation in D layer is due to Lyman series-alpha hydrogen radiation at a wavelength of 121.6 nanometre (nm) ionizing NO. Also the high solar activity can bring to raise the hard X-Rays (which have wavelength more than 1 nm) which ionize N_2 and O_2. Recombination of ions is at higher rate therefore there are more neutral air molecules. Medium frequency and lower high frequency radio waves are significantly weaken or subject to attenuation within the D layer, as while passing the radio waves let the movement of electrons in the layer which when collides with neutral molecules give up the energy. Lower frequencies undergo higher absorption as they tend to move the electrons farther, leading to greater chance of collisions. This is important reason for absorption occurring as a consequence of interaction of high frequency radio waves in ionosphere at 10 MHz and below, with progressively less absorption of HF. This effect is highest at 12:00 noon and is lesser at night due to rise in thickness , only a little amount of stratum stays due to cosmic rays (the high energy protons and nuclei moving in space with nearly speed of light)

An ordinary example for this is the vanishing of the distant AM broadcast band stations at the daytime.

During ‘solar proton events’ or ‘prompt proton event’ (‘when particles emitted from the sun are subject to accelerate either close to the sun during a flare or within interplanetary space from coronal mass ejection shocks’)ionization can reach awfully high levels in the D-region in high and polar latitudes. These very rare unusual events are termed as Polar Cap Absorption (PCA) events, since the increased ionisation considerably augment the absorption of radio signals passing through this region. The absorption level can in fact enhance by many tens of dB during intense events, which is sufficient to absorb most of polar region’s high frequency radio signals transmission. Such occurrences typically last lesser than 24 to 48 hrs.

E layer:

The E layer is the middlemost layer in ionosphere which extends from 90 km to 150 km above the surface of the Earth. Here the ionisation is because of the soft X-Ray (1 – 10 nm) and far ultraviolet solar ray's ionisation of molecular O_2. Generally at the oblique incident, this layer can reflect the radio waves of frequency 10 MHz and lower and a little bit of absorption on above frequencies. On the other hand , during the extreme sporadic E events, the E layer is chiefly determined by the competing the outcomes of ionization and recombination. During the nights, the E layer weakens, since the main source of ionization is no longer present. After sunset an enhancement in height of the E layer maximum increases its range to which the radio signals

can be travelled by reflection from the layer. This layer is also called 'Kennelly Heaviside layer' also known by the name 'Heaviside layer'.

E_s layer :

The E_s layer , also referred to as sporadic E-layer is designate by small, thin clouds of intense ionization, which can adhere reflection of radio signals , rarely up to 450 MHz . Sporadic E events can last for just a minutes to many hours. These unusual forms of radio propagation makes VHF-operating radio amateur very infatuated, as path for propagation that are commonly unreachable can open up. This propagation happen most frequently in the summer times when high signal levels maybe reached. The skip distances are commonly around 1640 km. Distances for one hop propagation can be around from 900 km to 2500 km. Double-hop reception is possible for over 3500km .

F layer :

The F layer or F region is also referred as Appleton-Barnett layer, named after the English scientist Edward Appleton and New Zeeland born physicist and meteorologist Miles Barnett. This layer stretches from about 150 km to more than 800 km from above the surface of Earth. Likewise, in rest of the ionospheres' sectors, the word 'layer' signifies the concentration of plasma and ionized gases. This region has the most number of electrons densities which suggests signals penetrating this layer will elude into space. The extreme ultraviolet (EUV or XUV) high energy ultraviolet radiation ionizing atomic oxygen O_2 led to electron production in dominant way.

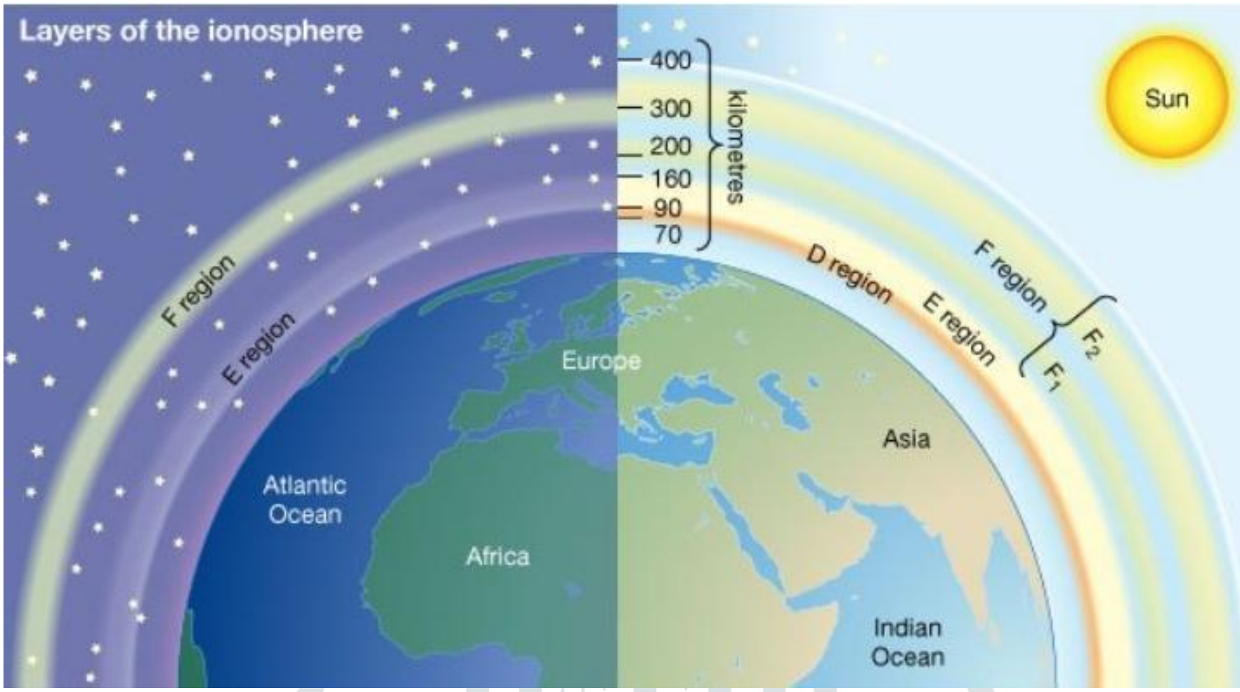

Figure 3: the day and night differences in layers of Earth's ionosphere

It is believed that F region comprises of two layers, F_1 and F_2 layers. Layer F_2 is a 'night and day' stratum and the secondary peak in the electron density profile labelled as F_1. The F_2 layer stays throughout day and night therefore responsible for most sky wave propagate and reflect normal incident frequencies $\leq$ (less or below critical frequency) approximately 10 MHz of radio waves; and absorbs longer distance HF or shortwave radio communications .

F_1 layer and F_2 layer:

The lower part of F region in ionosphere is F_1 layer and happens to exist at about 150 km to 220 km above the sea level of earth and exists only in day hours. Its composition is a collection of 3 items namely molecular ions O_2 and NO_2, and atomic ions O^+ . Above the F_1 area, atomic oxygen O becomes lighter particles tends to take up higher altitude above the turbopause (marks the altitude in the atmosphere below that chaotic changes in pressure and flow velocity in fluid motion dominates) (at ≈100 km, 60 miles). The atomic oxygen supplies the O^+ atomic ions that gather up the F2 layer. The F1 layer has round about 5×10^5 e/cm^3 (free e^- per cm^3) at noon and least sunspot activity. The density gets reduce to below 10^4 e/cm^3 at night. The layer F1 and F2 merges into one at night. Though commonly in its characteristics, it is not noticeable everywhere on all days. The principal reflecting layer throughout the summer season for path of 2,000 to 3,500 km is the F1 layer.

F2 layer is found at about 220 km to 800 km above sea level of earth. This layer is referred as 'principle reflecting layer of HF communications' throughout day and night. For one-hop F_2 propagation, the horizons limited distance is usually around 4,000 km. The F_2 layer has electron density about 10^6 e/cm^3. However, differences are usually major, disordered, and particularly pronounced during magnetic storms. The F layer nature is dominated by thermospheric winds.

INSISTENTLY REPETITIVE ANOMALY TO THE IDEALIZED BEHAVIOUR

The true shape of different layers in ionosphere is concluded by the help of Ionograms through computation. The structure of ionosphere is made by non-homogeneous structure of the electron or ion plasma that produces rough echo traces mainly seen at nights and at higher latitude and during disturbances.

WINTER ANOMALY

Since the sun shines directly on earth in summers, the F_2 Layer produces higher number of ions in daytime at the mid-latitudes. Other than that there exist seasonal changes in molecular-to-atomic ratio of neutral atmosphere results in ions an atom decrease in number in summer at higher rate. Thus, the increase in summertime loss devastates the increased production in summertime and hence the total F_2 ionization is actually lower in summer months. It's called Winter Anomaly. This anomaly is always there in northern hemisphere but usually not present in southern hemisphere due to less solar activity.

EQUITORIAL ANOMALY:

Equatorial anomaly's range is in between 20 degrees of the magnetic equator to both sides of equatorial line. A trough is formed in ionization in the F_2 layer at equator and at 17 degrees in magnetic latitude are formed the crests. The magnetic field lines of earth are horizontal at Earth's magnetic equator. The plasma in lower ionosphere is moved up by the solar heating and tidal oscillations. All this makes a sheet of electric current in E region and the horizontal magnetic field, forces ionization up into the F layer, accumulating at ±20 degrees from the magnetic equator. It's also referred as equatorial fountain.

EQUATORIAL ELECTROJET:

The winds driven by sun throughout the Earth results in solar-quiet current system in E region of earth ionosphere. Due to this current, an electrostatic field directed west-east in the dayside hemisphere of ionosphere is formed. At the magnetic inclination equator, where the geomagnetic field is in horizontal way, this electric field leads to an enhanced eastward flow of current within ± 3 degrees of the magnetic equator of earth, which is called equatorial electrojet.

SUDDEN IONOSPHERIC PERBURTATION /

GEOMAGNETIC STORMS:

In the phase where Sun is active, an emergent flash of enhanced brightness on the Sun, mostly observed near its surface and in close impendency/proximity to sunspot group often called as solar flare can occur that hit the sun exposed side of earth with hard and harmful X-rays. These rays infiltrate into the D- region, which leads to release electrons resulting in rapid increase of absorption, cause a high frequency radio blackout (3- 30 MHz) . In this time very low frequency of about 3-30 kHz radio waves will be reflected by D layer rather than E layer, where the increased atmospheric density will mostly raise the absorption of the wave and hence damp the wave.

Meanwhile the X-rays end, the sudden ionosphere perturbation or radio blackout ends as the electrons in the D region reconnect expeditiously and signal strengths come back to normal.

In March 2015, the ionosphere disturbances occurred, it was the strongest solar storm commenced on 17 March, 2015 i.e. St. Patrick's Day. It last for over 24 hours causing consequences on magnetosphere-ionosphere-thermosphere. The cause for the unexpected storm was due to the interaction of pair of Coronal Mass Ejection (CME) successively on 15 March; the cloud of plasma; and compression of very high speed winds hit the geomagnetic field density hence causing large amount of plasma precipitation & causing aurora sub storm activities.

In the below figure is shown the sequence of the interplanetary and Earth's magnetic parameters during 15–20 March 2015 are shown. The sudden storm commencement was recorded at ~ 04:45 UT on 17 March. The speed of solar wind and pressure considered by the Advanced Composition Explorer increased, respectively, from 400 km/s to about 500 km/s, and from approximately 300 nPa to about 500 nPa; meanwhile, SYM-H raised suddenly to 53 nT from a stationary state, the Kp index reached 5, and the IMF Bz component approached ~25 nT, pointing north. Thereafter, the development of the storm can be divided into three typical stages: the initial phase (~04:45–07:30 UT), the main phase (~07:30–22:45 UT), and the recovery phase (after 22:45 UT).

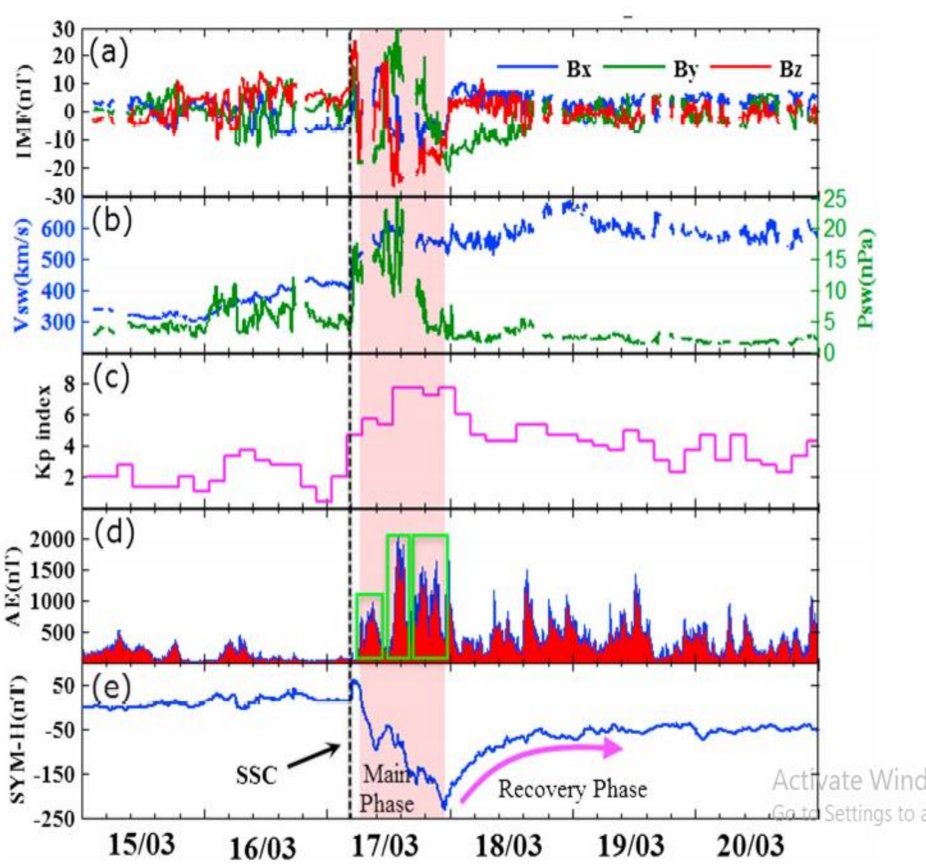

Figure: Shown variation in geomagnetic conditions during 15 March to 20 March 2015

a.) IMF Interplanetary magnetic field
b.) Velocity and Dynamic pressure of solar wind
c.) K_p index
d.) Auroral electrojet index
e.) SYM-H index

CONCLUSION:

We have studied and reviewed the basic fundamentals of model of ionosphere. The vertical model i.e. the D, E, F layers; persistent anomalies; and ionospheric perturbations have been discussed in introductory form. The geomagnetic storm of 17 March (St. Patrick's Day) ,2015 has been discussed with graphical variations of interplanetary geomagnetic conditions.

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