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Ionosphere Model Development using Regression Method

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ABSTRACT

For earth survival an ionosphere is most important and utmost noteworthy for vital satellite communiqué for the navigation positioning exactness persistence. It encompasses different number of layers subject to the quantity of electron density based on distance. So many ionospheric models of its kind are available to guess electron density with temporal determinations based on different research done within this era. GPS data are habitually castoff in these models. Because of that the essentiality is, a required of progressing ionospheric models to cope up with dissimilar time period for low latitudes of nation. Apart from this, an ionospheric tomography is not a well-posed problem. Ionospheric TEC bring into being concurrently in copious locations, which can be determined by a number of methods to overcome electron density. This paper is projected for the research of developing a method to estimate of total electron density which cover entire Indian region. Largely we can utilized satellite data and placed together by number of calculations. The organization of massive figures are intended the usage of data mining algorithms, and artificial neural network algorithms intended to guesstimate. A thorough study on ionospheric model development using regression method and further proposed idea based on literature can be seen in current research paper.

Keywords: Ionosphere Model Development, Artificial Neural Network, LSTM

1. Introduction

The ionosphere is very decisive and significant part related to the atmosphere of the globe. It is about 80 to 1000 km above the land and create very important layer for our mankind existence. It develops and contracts depending on the energy it engrosses from the sun (Wen et al., 2021). It contain basically three layers like D, E and F. To examine basic construction of the ionosphere can help society to increase correctness of the placement, timing, delicacy communications and navigations and for learning, discovering the connection between the upper atmospheric layers. The important aspects of this ionosphere layer is that it protect us from the hazardous ultra-violate rays coming from the sun. The deviation of ionospheric electron density is having noteworthy impacts for radio signals transmitting over the sky (Wen et al., 2021). Due to high amount of variation in the ionization process whenever signal travel from satellite to receiver it can cause delay by speed variation which can highly affect the accuracy of positioning system(Wen et al., 2021).

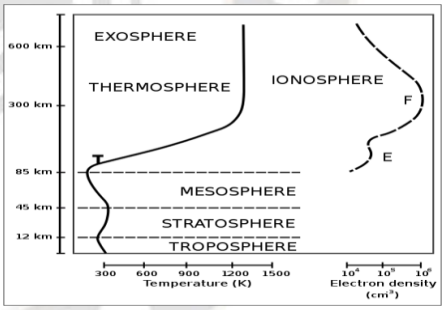

Fig:1 Relationship of Atmosphere & Ionosphere [21]

1.1 Electron Density

To build an Ionosphere model it is crucial to understand and find out the electron density. Ionosphere is having different attributes like electron density, ion, electron temperatures, Ionospheric composition, dynamics which keeps on changing with different latitude, altitude, and longitude. Also it has diverse variety during different duration of the day, sunspot cycle and magnetic activity. Ionization oscillations occur in the equatorial, North Pole and South Pole are identified larger whereas adequate changes in the mid-latitude province (Smirnov et al., 2023). So many methods to measure electron density of ionosphere has been discovered. The physics-based simulations, which gain arithmetic explanations of the essential calculations unfolding the ionospheric plasma, need refined forming codes that contain join

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with the unbiased atmosphere and magnetosphere. Organization of such simulations is computationally costly and thus difficult for functioning determinations (Smirnov et al., 2023). A substitute tactic to measure electron density is done over experimental modeling, which shows the connection among the input and output variables is designated way on the statistical demonstration of remarks(Smirnov et al., 2023).

2.0 Challenges and opportunities

From last few decades ionosphere model development is getting insight interest as reconstruction of Ionosphere Electron Density is very essential from different application based on navigation and positioning system or radio signal system. Different dataset for different locations have been used to construct electron density but as it is ill posed problem there is still need of more detailed research and work upon with new approaches. For so many years, the calculation of TEC was mainly depended on Ionosonders. It is done by utilizing reflections of ionosphere for different wavelengths and by monitoring lower side ionosphere.

2.1 Dataset

Literature cites different dataset has been utilized for diverse models like U.S. grounded GPS is utilized for global navigation satellite systems (GNSS) for delivering exposure of whole earth. Currently supplementary satellite systems like GLONASS (Soviet Union), Galileo (European Union), BeiDou (China), and QZSS (Japan) also established for delivering a worldwide and provincial area. From decades to till now, for the Indian region, GPS satellites utilized for each climate situations. To encounter the petition for better correctness Indian Space Research Organization (ISRO) has settled "GPS Aided GEO Augmented Navigation" (GAGAN), in cooperation with the Airports Authority of India (AAI). India is having particular satellite navigation platform, entailing of the GNSS augmentation system, known as GAGAN in accumulation to individual prime navigation system "Indian Regional Navigation Satellite System (IRNSS)" (Mukesh et al., 2019). Separately from the navigation uses, the signals delivered using these organizations, moreover it can applied to numerous other resolutions. The consumption of the system rest on upon nature and the excellence of data that we acquire from it. The IRNSS is an ISRO's inventiveness to deliver self-determining satellite navigation services comprising position, velocity and time to users for whole Indian region (Mukesh et al., 2019). It is hypothetical to offer two types of services viz., standard positioning service (SPS) for civilians and restricted service (RS) service for strategic users.

3. Existing model problem survey

Based on different literature, it cites that so many Ionospheric model are made to predict the total electron density with spatial and temporal purposes. But these models are generally using the GPS satellite data. Also these models are developed for typically fix time duration. Ionosphere has so many air attribute which directly or indirectly affect the number of electron present in Ionosphere. Existing models have taken limited parameters. The variation for trail, pace of radio waves in the ionosphere is having vast effect on the exactness of satellite navigation systems for example GPS/GNSS. Evading fluctuations for ionosphere TEC can announce huge amount of fault in the position scheming. There is a necessity to construct Ionospheric methods for latitudes of Indian region with different time period to forecast electron density.

4. Methodology

4.1 Total Electron Content

Ionosphere consist of lot many electron with the process of ionization. Due to this ionization process we can get the advantage of so many application which are directly based on these number of electron present in this layer during different periods of time (Wen et al., 2021).The overall amount of electrons existing within a way of a radio transmitter and receiver is known as the Total Electron Content (TEC). These existing electron in the different layer of ionosphere effect the Radio Waves. To monitor TEC parameter can help us for ground to satellite communication and satellite navigation, also help for possible space weather impressions (Wen et al., 2021).Forecasting of TEC can lead us to disentangle several issues. At current, numerous universal TEC calculation methods were created and assessed, like Klobuchar model for assessing Global Positioning System (GPS); International Reference Ionosphere (IRI) model has been indicated ionospheric parameters; to guess the probability of electron density NeQuick model developed, and Galileo system implemented NeQuick-G model for its single-frequency users (Wen et al., 2021).

$$I = (40.3/f^2) * TEC \quad (1)$$

Above formula (1) define the I as Ionospheric delay which is in meter and f stands for frequency in hertz, Total Electron Count is in Electron per meter square which is represented by TEC.

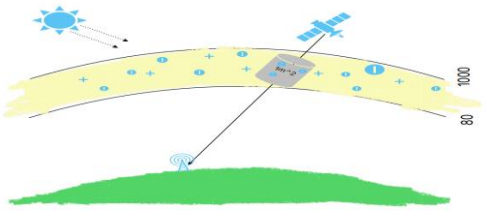

Fig.2. Slant TEC (STEC) from a satellite to a receiver

4.2 Importance of Regression Analysis

Regression analysis aids in determining the variables influencing data insights. It can help you determine which elements are important and how much of an impact they have on an outcome. We refer to these elements as variables.

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You must understand two primary categories of variables. The dependent variable is the primary factor on which you are concentrating. This variable, which depends on one or more other variables, is frequently measured as a result of analyses. Independent variables are the elements or variables that affect your dependent variable. These kinds of variables are frequently changed for analysis. They go by the names explanatory and predictor variables as well.

4.3 Simple linear regression

The first step involves fitting a basic linear regression model to forecast TEC values. The daily TEC statistics for March are compared using a correlation test. When there is a linear relationship between the dependent variable (DV) and the independent variable (IV), this kind of regression is appropriate. The formula for fitting a basic linear regression model with first-degree parameters is provided by equation. Because of the strong correlation between the TEC values on different days, it is possible to deduce the TEC values for a given place from one another. To anticipate the TEC of a subsequent day, input features such as the time of day and TEC data are employed. Seventy percent of the data are utilized for training the model, and the remaining data are used for testing.

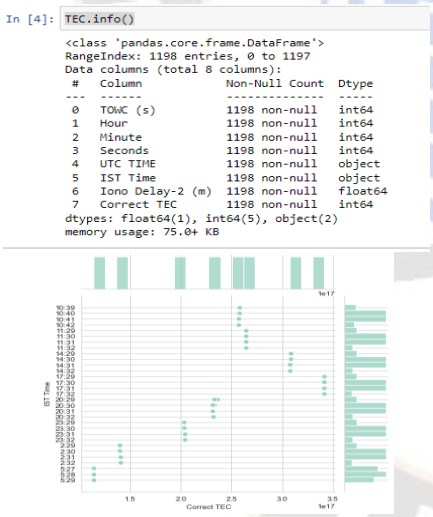

Fig.3. Dataset implementation with TEC vs Time

4.4 Result

Train Data	Test Data	MAE	MSE	RMSE
50	50	27.49	1031.27	32.11
70	30	28.97	1147.73	33.88
90	10	11.6	339.2	18.42
95	5	16	460.8	21.47

Table 1. Results

5. Conclusion

Regression analysis is a potent technique for leveraging historical data to draw statistical conclusions about the future. It finds the relationships between variables that appear in a dataset, as well as the strength of these relationships and how important they are to the results. Its remarkable adaptability makes it a valuable statistical analysis tool across sectors. Here results are giving us good variation but still it is not enough as there are lots of dataset with varying in nature and other parameters also depends on TEC variability so just regression method is not enough to find out TEC prediction in different region with different seasons. So in future this research is intended to work with latest deep learning algorithms to find out better accuracy in TEC prediction.

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