ABSTRACT

Background:

The prediction of earthquakes (EQs) is a challenging problem, even with the available state of art technology and high resolution data of today. It is of course important to note that, with the growth of quality data pool, our knowledge on ‘EQ preparatory activities’ have advanced significantly. The scientists are therefore looking for EQ signature from the lithosphere to upper atmosphere. The process has opened up wide horizons to look into with new methods for EQ precursor. One such approach that has gained an importance in recent times is the use of electromagnetic (EM) signals. This realm provides wide spectra of EM frequencies from Low Frequency (LF) to Very High Frequency (VHF), for studying their varied response to EQ time ambiance of the transmission media, and we have seen some significant advantage in this school of studies. The thesis deals with this area of searching for EQ associated effects mainly by using very high frequency data. The aims and objectives are given below:

Aim of the Study:

The main aims of the study are –

- To adopt Electromagnetic techniques for extraction of EQ time changes in the atmosphere and hence to identify the EQ precursor.
• To understand the Physics and dynamics of the atmosphere during and prior to a low latitude earthquake.

• To understand the coupling processes between lower and upper atmosphere activated by EQ preparatory processes. The aspect includes the role of seismic time E×B drift around Appleton anomaly zone and of Radio Refractive Index (RRI) gradient of near earth environment.

For this purpose the following analysis are taken up –

1) Mapping of TEC variation from GPS and geostationary satellites for two solar activity periods.

2) Profiling of tropospheric parameters from ground based, Radiosonde and satellite observation.

3) Model computation using data mining techniques on identification of EQ time TEC anomaly.

The approaches taken with these aims are –

(i) TEC peak detection method.

(ii) TEC profile shape as EQ time parameter

(iii) Dynamic Time Warping (DTW) techniques for determining certainty factor related to EQ time TEC anomaly

(iv) Mapping of satellite azimuth and extraction of seismic time anomalous satellite azimuth position.

(v) RRI and RRI gradient and their EQ time modifications.
The TEC data for the work are mainly collected over Guwahati (geographic latitude 26.2° N, geographic longitude 91.7° E, geomagnetic latitude 15.2° N, dip angle 37° N, magnetic latitude 20.64° N), from geostationary satellite and GPS. The tropospheric parameters like temperature, pressure leading to RRI are collected from Regional Metrological Centre (RMC). The EQ data and DST values are taken from the web sites USGS National Earthquake Information Center (http://earthquake.usgs.gov/earthquakes/) Koyama Astronomical Observatory (http://www.kyoto-su.ac.jp/english/research/observatory.html) respectively. Daily Sunspot No. are collected from Solar Influence Data Analysis Centre (SIDC) (http://sidc.oma.be/), Geomagnetic data are also collected from Daily Solar Space Weather & Geomagnetic Data Archive (http://www.k1tt.net/technote/kn4l5/kn4l5.html)

As supporting inputs global TEC maps are also utilised. The atmospheric profiling obtained from Wyoming website is also associated with TEC parameter.

The work is presented in five chapters –
Chapter: 1

The Background of the Problem taken under Study:

The chapter discusses the review work related to EQ precursor study adopting different EM techniques. The justification on the use of TEC in this EQ precursor study is put forwarded. The imprints of EQ on TEC variations obtained from GPS as well as from geostationary satellite are reviewed in the context of pre seismic time modification of the atmosphere. The importance of the location Guwahati, the main study station is also brought into the focus because the station lies at the crest of the Appleton anomaly, the width of which undergoes modification by the EQ preparatory processes. Further in association with upper atmospheric variabilities the background of possible modification in the tropospheric parameters like temperature, laps rate, RRI are also discussed by considering relevant sources leading to such changes in the NE region.

Finally the processes of coupling that are active between the lithosphere-atmosphere during an EQ are also discussed relevant to the location of Guwahati that lies on the global seismic fault system.

Chapter: 2

Experimental Techniques Adopted in this Study and Data Source:

The chapter gives brief description of experimental techniques adopted in this work. A brief description of the experimental arrangement made for TEC measurement from
geostationary satellite and GPS is given along with the theoretical background on TEC derived from propagating signal character transmitted from a satellite, while traversing through the ionosphere. The extraction techniques and use of other associated parameters like satellite azimuth, elevation and number of satellite coming into the view of GPS receiver are also discussed in the chapter. The basic mode of observation on ground based and topside peak ionisation density of F-layer i.e., $N_mF_2$ is also brought into analysis. Further measurement techniques on lower atmospheric parameters on temperature, lapse rate and RRI relevant to this study are also discussed.

Chapter:3

Examination of the Role of Solar Geomagnetic Factors on Total Electron Content Features:

In this chapter an extensive analysis of TEC data covering two solar activity periods (both high and low) is done and basic characteristic features of TEC of Guwahati are mapped in seasonal and diurnal context. The approaches for filtering the effects of geomagnetic disturbances and magnetic storm on TEC are also elaborated in the chapter. Saturation of magnetic effect on TEC is also highlighted as observation periods cover both high and low solar activity periods. The post noon and post sunset enhancements on TEC as a result of ExB drift phenomena are examined with respect to solar and
geomagnetic activity condition. These features are then utilised for formulating a reference TEC profile while identifying EQ precursor.

Chapter: 4

Approaches adopted for Extraction of EQ Precursor: Presentation & Interpretation of Results in terms of System Dynamics:

In this chapter the approaches adopted for extraction of earthquake induced features from TEC are discussed. The selection criteria for framing of a reference template are made with reference to earlier discussion in chapter 3. The EQ precursor study is started with TEC peak detection method where TEC peak of a particular day is taken as a reference parameter. The result obtained using this technique is presented with the number of EQ case studies. The limitation of this 'Peak detection method' is also highlighted through the case studies. This technique is upgraded next by adopting 'Profile shape' as the input parameter and the study presents that it removes the ambiguities as observed in the earlier approach.

The model approach used for EQ precursor study is discussed elaborately in this chapter. Here data mining technique is adopted where, a dynamic programming design known as Dynamic Time Warping (DTW) framed to identify mismatch between two time series and to determine the deviation between the two. Here, one of the time series is framed from quiet day TEC profiles while the second series is for any other day. The two series are compared by calculating the magnitude of 'like-to-like' matches. Based on this
matching, a parameter called the 'certainty factor' is defined to identify earthquake cursors. This algorithm is then applied for recognizing earthquake induced features in TEC. It is seen that Dynamic Time Warping algorithm produces better predictability than the other methods that discussed.

The role of troposphere in the evolution of the processes of enhancement or depletion on TEC prior to an EQ is examined by associating with TEC the lower atmospheric variables like temperature, pressure, Humidity that may result to modification in effective earth radius factor. For this purpose anomalous view of satellite received by the GPS antenna at GU are mapped. The chapter describes the processes adopted for identifying the anomalous satellite azimuth position in association of the epicentre of the EQ. For this purpose major China EQ of 2008 are also analysed and the identified epicentre location by this approach is highlighted. The resultant coupled dynamics between lower and upper atmosphere are suggested.

Chapter: 5

Overall conclusion and Future Study:

The overall conclusions of the study are presented in this chapter. The analysis shows that compared to the high solar activity period EQ precursor identification is more reliable during low solar activity period by this method. It is also noted that TEC peak detection method may offer false alarm of an EQ because of modification of the peak
magnitude in a geomagnetically disturbed condition. In this respect TEC profile shape is identified as better approach though a number of filtrations are necessary before extraction of EQ precursor. The DTW technique that takes the entire shape of the profile in determining the certainty parameter seems to be a reliable technique. It is also observed that along with the TEC peak detection and Profile shape, the other relevant parameters like azimuth of the satellite, number of satellite seen by the GPS receiving antenna are essential inputs in locating epicenter position. The dynamical coupling between lower and upper atmosphere is discussed by considering EQ generated electric field at the epicentre position along with tropospheric modification in the path between the epicentre and the receiving station. The role of Appleton anomaly and the modification in the ExB drift process by EQ preparatory processes are brought into ambit of discussion relevant to EQ time changes in TEC.

Finally the following conclusions are drawn:

1. The techniques adopted using TEC peak and profile shape can give the EQ precursors but not epicentre position.

2. The DTW model can offer prompt detection of EQ precursor with a finer resolution.

3. Satellite azimuth and the number of satellites coming into the line of sight of the receiving antenna along with the TEC variations can offer EQ precursor as well as the epicentre position.
4. Both ionospheric and tropospheric parameters are relevant in modifying the system dynamics prior to an EQ.

In future, it is planned to associate global TEC features specially growth and development of anomaly relevant to seismic time with that observed in the particular location like Guwahati. Also it is planned to introduce clustering techniques in DTW model for immediate model prediction and identification of precursor as well as of the epicentre.

References:


5. Devi M, Barbara A K, Ruzhin Yu Ya, Depueva A H: Beyond the horizon propagation of VHF signals, atmospheric features and earthquake, Electronic journal, Investigated in Russia, 129e.pdf. 2007


