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Study the relationship of earthquake and ionosphere using IRI TEC for Education

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ABSTRACTS

This research is aimed to study and analyze the relationship between the earthquake events and the disturbance of ionosphere. The method is by using the International Reference Ionosphere (IRI) model to get Total Electron Content (TEC) values and then find the correlation on earthquake events and ionosphere. The result is to be correlated at 0.056, which shows the evidence of correlation on earthquake events and ionosphere. For the future work, we will study the significant on the development of earthquake warning system . This study can be used for educational purposes.

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1. INTRODUCTION

Earthquakes are natural phenomena caused by vibrations or shaking of the earth's surface, occurring at any time without humans being able to tell us and where they will occur, causing damage to their entire property. Various buildings, including the loss of life, earthquakes may be related to changes total electrons in ionosphere (Heki, 2011).

The scientists found that earthquakes effect on Total electron content (TEC) changes. Most TEC changes occur after large earthquakes (Heki, 2011; Cahyadi & Heki, 2013; Afraimovich *et.,al* 2014). The ionosphere is a layer of ionized plasma clusters that congregate to a density enough to reflect radio waves at frequencies lower than the high frequency band, 50-2,000 kilometres above the earth, with an electron density of 10^{10} -10^{12} electrons per cubic meter (Arikan *et al.,* 2008). TEC is an important ionospheric parameter which directly affects the propagation of radio waves through the ionosphere (Yeh *et al.,* 1979). TEC computation can be detracted from International Reference Ionosphere (IRI) (Kenpankho *et al.,* 2013) and can be used to find the correlation for relationships between the earthquake events and the disturbance of ionosphere.

We aim to study and analyze the relationship between the earthquake events and the disturbance of ionosphere. The method is by using the International Reference Ionosphere (IRI) model to get Total Electron Content (TEC) values and then find the correlation on earthquake events and ionosphere.

We expect that TEC results show a significant relationship with earthquake events and guide the development of earthquake alarm and telecommunication systems. This study can be used for educational purposes.

2. MATERIALS AND METHODS

2.1 GPS TEC data

The dual-frequency Global Positioning Satellite (GPS) receiver is used for the Global Positioning Satellite Total Electron Content (GPS TEC) measurement system, which consists of a micro strip antenna, an amplifier, a TEC Meter, and a computer. The GPS receiver starts functioning when it continuously receives between four and 12 GPS signals that will lead to the computation of the Slant Total Electron Content (STEC) values.

The STEC from a satellite to a receiver can be obtained from the differences among GPS frequencies (f_1 and f_2), the pseudoranges (P_1 and P_2), and the difference between the carrier phases (L_1 and L_2) of the two methods (Blewitt, 1990; Kenpankho, 2011).

$$\mathrm{STEC} = \frac{2(f_1 f_2)^2}{k(f_1^2 - f_2^2)}(P_2 - P_1) + \tau^r + \tau^s \qquad (1)$$

or

$$\mathrm{STEC} = \frac{2(f_1 f_2)^2}{k(f_1^2 - f_2^2)}(L_1\lambda_1 - L_2\lambda_2) + \varepsilon^r + \varepsilon^s \qquad (2)$$

Once STEC is known, we use STEC to find the Vertical Total Electron Content (VTEC). Where VTEC, in el/m^2, can be calculated and analyzed from Kenpankho et al. (Kenpankho *et al.,* 2011) and Ma and Maruyama (Ma & Maruyama 2008) following as

$$\mathrm{VTEC} = \mathrm{STEC} \times \cos(x) \qquad (3)$$

where the zenith angle x is expressed as

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$$x = \arcsin\left(\frac{R_E \cos(\alpha)}{R_E + h}\right) \quad (4)$$

where α is the elevation angle of the satellite, R_E is the mean radius of the Earth, 6,378 km, and h is the height of the ionospheric layer, which is assumed to be 450 km (Kenpankho *et al.,* 2011; Ma & Maruyama, 2003).

The cycle slip correction can typically be made with the aid of pseudorange difference information. To obtain the VTEC, it can compute as following as

$$\mathrm{VTEC} = (\mathrm{STEC} - b_s - b_r) \times \cos(x) \quad (5)$$

where b_s and b_r are the estimated satellite and receiver biases, respectively (Kenpankho *et al.,* 2011; Ma & Maruyama, 2003).

2.2 IRI TEC data

The International Reference Ionosphere (IRI) is an international project sponsored by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). Several steadily improved editions of the model have been released. For given location, time, and date, IRI provides monthly averages of the electron density, electron temperature, ion temperature, and ion composition in the ionospheric altitude range. IRI can be found from IRI model version 2016 (see **Figure 1**). site: https://ccmc.gsfc.nasa.gov/modelweb/models /iri2016_vitmo.php.

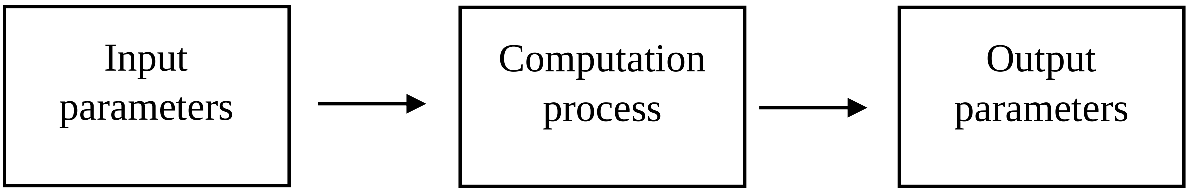

Figure 1. IRI program process.

Input parameters
- Date and Time
- Latitude
- Longitude
- Height
- Profile type
- Range

Output parameters
- Total Electron Content (TEC)

2.3 Earthquake data

For earthquake events, the earthquake data is received from Earthquake Observation Division site: https://earthquake.tmd.go.th/lesson.html. Earthquake data has been recording since 2007-2020 and classified in **Table 1.** In this research, according to the earthquake magnitude 1-2 is rarely effective on TEC, we focused on the earthquake magnitude starting at 3 and above for comparing with TEC.

Table 1. Information of magnitude

Magnitude	Information
1-2.9	Hanging objects may swing.
3-3.9	The vibrations may be like a passing truck.
4-4.9	Windows may be broken, cause small or unstable objects to fall.
5-5.9	Furniture moves, chunks of plaster may fall from walls.
6-6.9	It damages to well-built structures, severely damages to poorly built ones.
7 or more	Building is displaced from foundations, things crack in the earth, and underground pipes broken.

2.4 Correlation coefficient

The correlation coefficient can be calculated following as

$$r = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum(x_i-\bar{x})^2\sum(y_i-\bar{y})^2}} \quad (6)$$

where r is the correlation coefficient, x_i is 1st variable data, y_i is 2nd variable data, $\bar{x}$ is 1st variable data mean, and $\bar{y}$ is 2 nd variable data mean.

3. RESULTS AND DISCUSSION

The results show the relationship between the earthquake events and the disturbance of ionosphere by using the IRI (International Reference Ionosphere) model and earthquake events as shown in **Figure 2**. The correlation coefficient is 0.056. This result can be implied that the magnitude above 4.1 gives the TEC value mostly above 10 TECU. The results show that the number on earthquake magnitude is high, the amount of TEC increases. At the results, we discuss that there are the significant events that the earthquake is related to the disturbance of ionosphere.

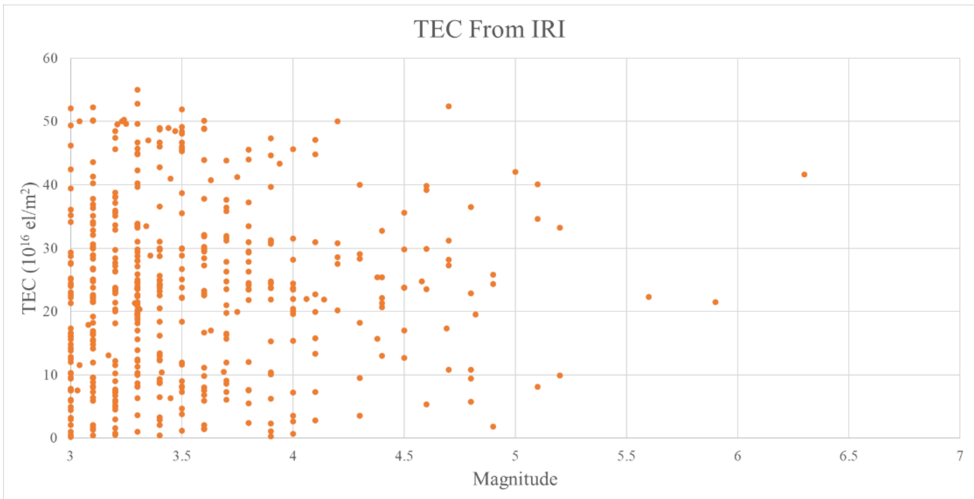

Figure 1. The relationship between the earthquake magnitudes and the disturbance of TEC from IGS.

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4. CONCLUSION

At the result and discussion, there are the significant events that the earthquake is related to the disturbance of ionosphere which shows the evidence of correlation on earthquake events and the TEC values . For the future work , we will study the significant on the development of earthquake warning system . This study can be used for educational purposes.

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