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Effect of ultraviolet radiation on total electron content in global positioning system observations

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ABSTRACT

Climate is one of the basic elements for understanding natural phenomena and the development of civilizations throughout history. Climate change determines most of the modifications of human nature and culture, as human must adapt to changing conditions which are sometimes an important element that can enhance or threaten its existence. This study aims to determine the characteristics of changes in the total electron content (TEC) and determine the radiation has influence to TEC through observing the global positioning system (GPS) in the ionosphere. In addition, the TEC is a measure of ionospheric parameters that affect the radiation that occurs. This study uses secondary data obtained from the Cibinong Spatial Global Station in 2008 – 2012. This research was conducted as a comparison of the TEC and extreme ultraviolet (EUV). The method used is a simple statistical method which seeks the maximum and minimum the TEC and EUV data, as well as the correlation method to relate the coefficient of determination TEC and EUV. As the results the maximum TEC value is 55.895 TECU which occurred in 2012 at 7 unit time (UT) and the minimum TEC value is 1.955 TECU which occurred in 2010 at 22 UT. The correlation ratio between the TEC and EUV is directly proportional, where the higher the value of the TEC, the higher the EUV value. In closing, TEC and EUV are influence by solar activity.

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1. INTRODUCTION

Climate is one of the basic elements for understanding natural phenomena and the development of civilization throughout history. Climate change determines most of the modifications of nature and human culture, because humanity must adapt to changing conditions that sometimes become important elements that can improve or threaten its existence [1]. A series of changes in the structure and composition of the earth have occurred since its formation as one of the planets in the solar system until now. These changes affect all its main parts, namely the atmosphere, hydrosphere, geosphere and biosphere. Geographic differences in solar radiation, which are much higher at the equator than at the poles, result in air mass movements. The heated air mass in the equatorial region causes severe rainstorms when the hot air rises. Climate variation is a major factor in the diversity and emergence of new species [2, 3]. The electron content in the ionosphere is influenced by several factors including geographic latitude and longitude, local time, solar activity, and geomagnetic disturbances [4]. The reaction of the Earth's magnetosphere-ionosphere system to variations in the solar wind and interplanetary conditions is a major concern for research in the context of Space Weather. TEC also provides a comprehensive picture of the ionosphere and has many practical applications such as satellite navigation, delay time and range error correction for single-frequency GPS receivers [5, 6].

To see the characteristics of the ionosphere ahead of increased solar activity in the low latitude equatorial sector of Indonesia, the ionospheric TEC data from the Pontianak GISTM observation used were data from 2011, which at that time was a moderate phase ahead of the maximum peak of increased solar activity cycle 24 [7]. To determine the level of variation during the 2011 period, parameters such as monthly median, standard deviation and relative variation or TEC variation index were determined, namely the standard deviation X 100 divided by the monthly median. The analysis carried out was a study of seasonal variations and the correlation between the percentage of relative variation of VTEC to solar activity, namely the number of sunspots [8, 9]. To obtain this ionospheric correction, real-time TEC data and a method are needed to determine the TEC correction. Commonly used methods include real-time two-dimensional ionospheric tomography models and ambiguity resolution techniques [10-12]. Real-time two-dimensional ionospheric tomography models can provide better than 1 TECU (10 cm at L1-L2) precision in double difference slant total electron content (STEC), while ambiguity resolution techniques have enabled DGPS accuracy to be improved from meter to decimeter levels [13].

GPS data has been widely used for research on ionospheric disturbances caused by nature or man-made, such as earthquakes [14, 15]. This study was conducted to determine the effect of ultraviolet radiation on the ionosphere based on total electron content (TEC) data obtained from global positioning system (GPS) data. TEC values are derived from GPS observation data from fixed control network stations or known as continuous operating reference stations (CORS) and BIG Geospatial Information Agencies. Dual-frequency GPS receivers can eliminate ionospheric delays through linear combination. Practical TEC variability is important in navigation and communication, has been reported by many researchers at the equator, low, middle and high [16].

Radiation is a form of energy emitted by any object that has a temperature above absolute zero and is the only form of energy that can propagate in the vacuum of outer space. Solar radiation is an electromagnetic wave consisting of an electric field and a magnetic field [17-20]. The sun emits 56×10^{26} calories of energy every minute. From this energy the earth receives 2.55×10^{18} calories or only 0.5×10^{9} calories. The existence of the atmosphere that covers the earth's surface plays an important role in the survival of organisms on earth. The atmosphere provides gases essential for life on earth, such as oxygen and carbon dioxide [21]. In addition, the atmosphere also protects life on earth by absorbing ultraviolet radiation from the sun and reducing the temperature difference between day and night. The function of the atmosphere is to keep the temperature on earth warm, protect the earth from outer space objects and as a filter against short-wave sunlight such as alpha rays, gamma rays, beta rays and ultraviolet rays. Therefore, the atmosphere plays an important role in reducing the negative impacts of ultraviolet radiation [22, 23]. Extreme space environmental conditions due to solar activity can cause serious effects on satellites, both anomalous effects and orbital decay. Orbital decay is caused by an increase in atmospheric density, especially on satellites in low orbit. Lapan-Tubsat and the next generation of Lapan satellites will be placed in low orbit so it is necessary to know the effect of EUV radiation and geomagnetic activity on the density of the atmosphere it crosses [24]. Ultraviolet (UV) rays have a wavelength range between 400 – 100 nm which is between the X-ray spectrum and visible light. Based on its wavelength, UV rays are divided into three, including UV-A or long wave (black light) with a wavelength ranging from 380 – 315 nm, UV-B or medium wave (medium wave) with a wavelength between 315 – 280 nm, and UV-C or short wave (short wave) which has a wavelength between 280 – 100 nm [25].

This study explains the effect of ultraviolet radiation on variations in TEC from GPS observations. TEC variations include extreme ultraviolet, geomagnetic storms, and atmospheric waves. This study aims to determine the characteristics of changes in TEC values and to determine how much radiation affects TEC through observations of a GPS on the ionosphere. In addition, TEC is a measuring instrument for ionospheric parameters that affect the radiation that occurs. Therefore, this study was conducted as a comparison of TEC and EUV values.

2. RESEARCH METHODS

The methods used in this study are quantitative and qualitative approaches (see Figure 1). The quantitative approach is used to collect samples and variables, while the qualitative approach is used to describe the results, there are also tables and diagrams. TEC data collection is carried out using a combination method between phase (L) and pseudo range (P) measurements which are slanted TEC and mathematically. Researchers collect data by recording and converting data directly from data sources using predetermined applications.

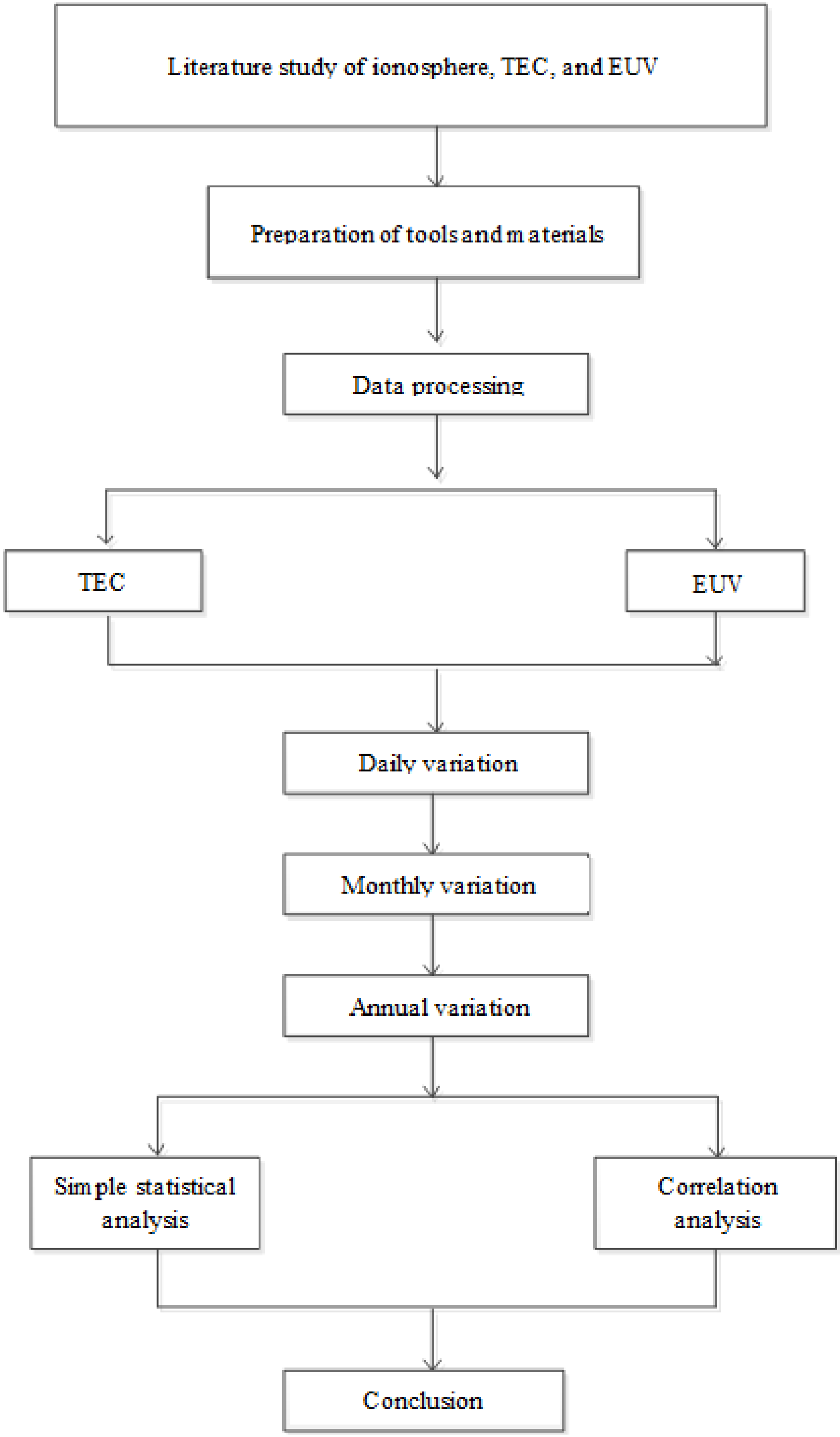

Figure 1. System diagram.

The tools and materials used in this study are such as computers as tools for data processing. Data retrieval is carried out by identifying the observation time first. Then the data is downloaded from the server, the data needed from this study. EUV radiation observation data and Cibinong TEC data. The analysis in this study is divided into two, namely simple statistical analysis and correlation analysis. Simple statistical analysis looks for the maximum and minimum values of TEC and EUV data while correlation analysis connects the determination of the coefficient to obtain its own function. This analysis uses the years 2008 – 2012. After obtaining the correlation analysis, we can compare in which month and year the solar activity is highest and the solar activity is lowest.

3. RESULTS AND DISCUSSIONS

3.1. Statistical Results of TEC

This calculation aims to determine the pattern of changes in the TEC value for 24 hours, monthly and annual medians with an observation period of 5 years starting from January 1, 2008 to December 31, 2012 or 1 days of year 2008 to 366 days of year 2012. The statistical results obtained are in the form of a graph of TEC values (TECU) against time (UT).

3.1.1. TEC Data Results January 1 (2008 – 2012)

Figure 2 shows almost the same change in TEC value from the first day of 2008 to the first day of 2012.

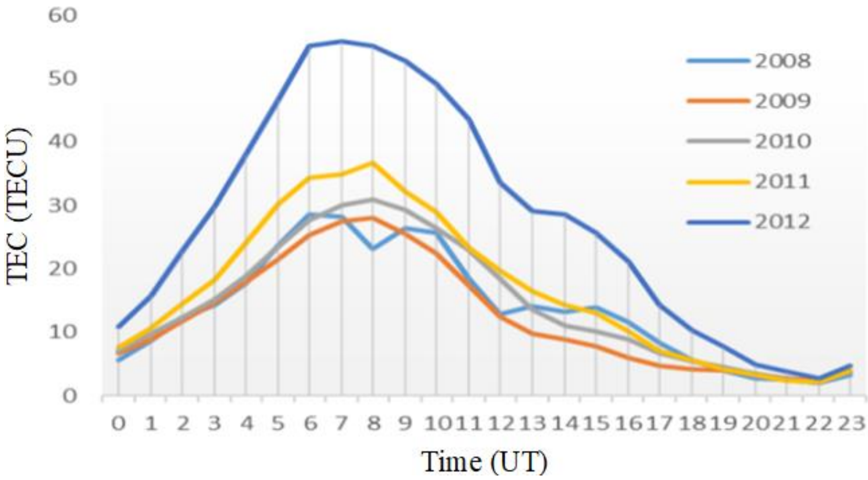

Figure 2. TEC change value January 1 (2008 – 2012).

The TEC value tends to be constant at 17 UT to 22 UT or in local time from 00.00 WIB to 05.00 WIB. Then the similarity of the maximum TEC value occurs during the day between 6 UT and 8 UT or in local time at 13.00 WIB to 15.00 WIB. The maximum TEC value occurred in January 2012 at 7 UT or in local time at 14.00 WIB noon with a value of 55.895 TECU. The cause of the maximum TEC value is because at that hour it is influenced by solar activity so that the number of electrons increases. The minimum TEC value occurred in January 2010 at 22 UT or in local time at 05.00 WIB with a value of 1.955 TECU. The cause of the minimum TEC value is due to low activity or influence from the sun.

3.1.2. Monthly TEC Data Results (2008 – 2012)

3.1.2.1. First 4 Monthly TEC Data Results (2008 – 2012)

Figure 3 shows almost the same TEC value changes from January to April (2008 – 2012). The resulting TEC values tend to be constant, where the maximum average TEC value from January to April occurred in 2012 due to the influence of fairly strong solar activity so that the number of electrons increased. The minimum average TEC value from January to April occurred in 2009 due to low solar activity.

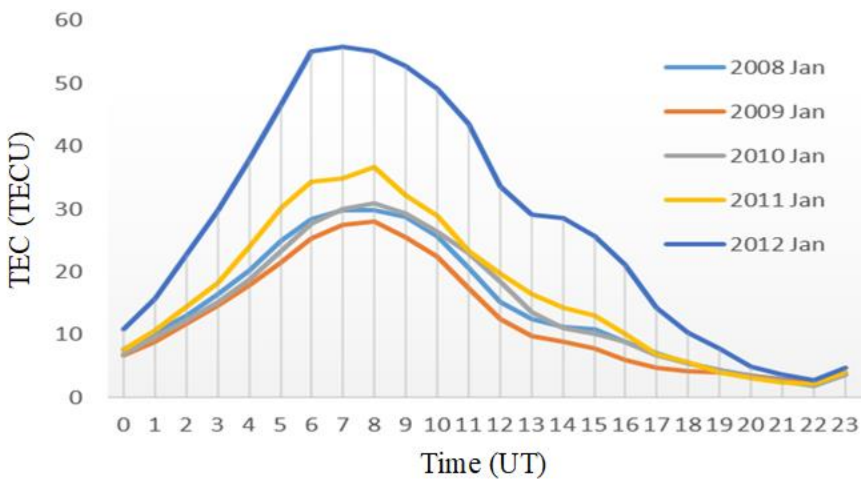

Figure 3. First 4 monthly TEC values (2008 – 2012).

3.1.2.2. Second 4-Month TEC Data Results (2008 – 2012)

Figure 4 shows almost the same TEC value changes from May to August (2008 – 2012). The resulting TEC values tend to be constant, where the maximum average TEC value from May to August occurred in 2012 which was caused by the influence of quite strong solar activity so that the number of electrons increased. The minimum average TEC value from May to August was not so constant where in July the minimum average TEC value occurred in 2008 while for May, June and August it occurred in 2009. The cause of the minimum TEC value was due to low solar activity. The change in TEC value in the second 4 months was low compared to the change in TEC value in the first 4 months.

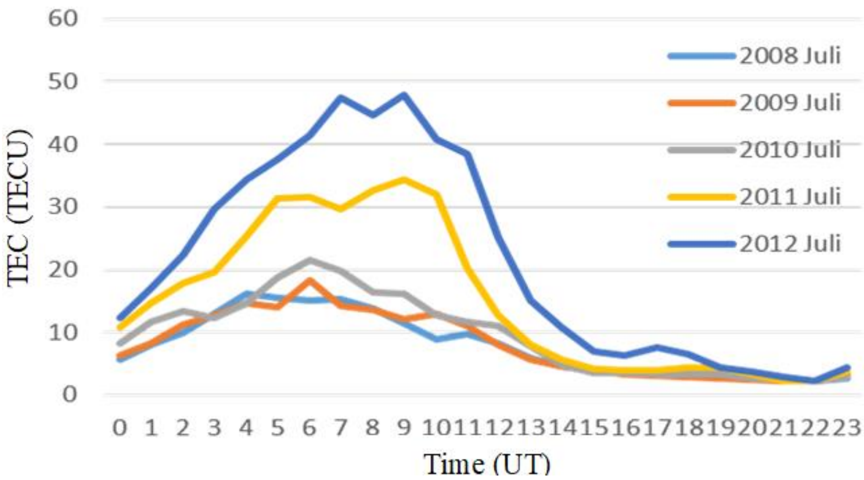

Figure 4. Second 4-month TEC values (2008 – 2012).

3.1.2.3. Results of the Third 4 Monthly TEC Data (2008 – 2012)

Figure 5 shows a change in TEC value that is not so constant from September to December of the year (2008 – 2012), where the maximum average TEC value in October occurred in 2011 while the maximum average TEC value in September, November and December occurred in 2012 which was caused by the influence of quite strong solar activity so that the number of electrons increased. The minimum average TEC value from September to December was not so constant where in September the minimum average TEC value occurred in 2009 while for October, November and December it occurred in 2009. The cause of the minimum TEC value was due to low solar activity. The change in TEC value in the third 4 months is higher compared to the change in TEC value in the first 4 months and the second 4 months, where in September to December the solar activity is so strong to the earth compared to other months.

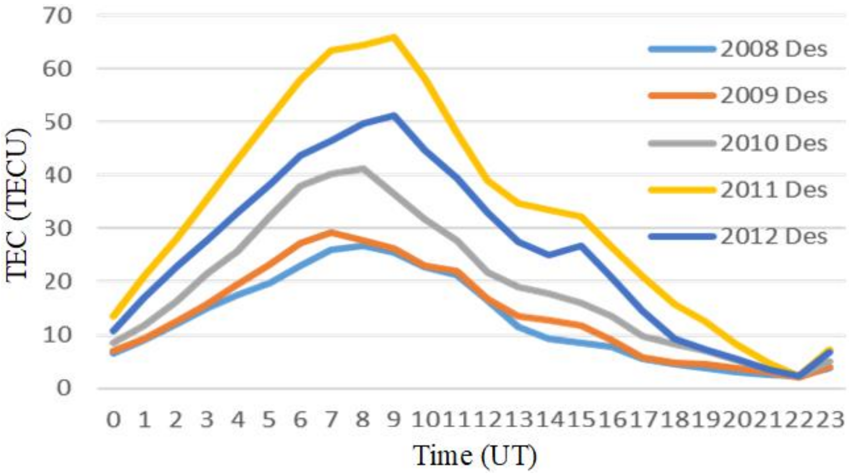

Figure 5. Third 4 monthly TEC data (2008 – 2012).

3.1.3. Annual Data Results

The results of this Annual TEC data are obtained from the results of daily and monthly TEC data. Thus we can find out the maximum annual median TEC value occurred in 2012 with an average annual TEC value of 29.68622 TECU and the minimum TEC occurred in 2009 with an average annual TEC value of 12.00182 TECU. Meanwhile, the maximum average TEC value occurred in October, namely 25.253 TECU and the minimum average TEC value occurred in July, namely 12.31583 TECU.

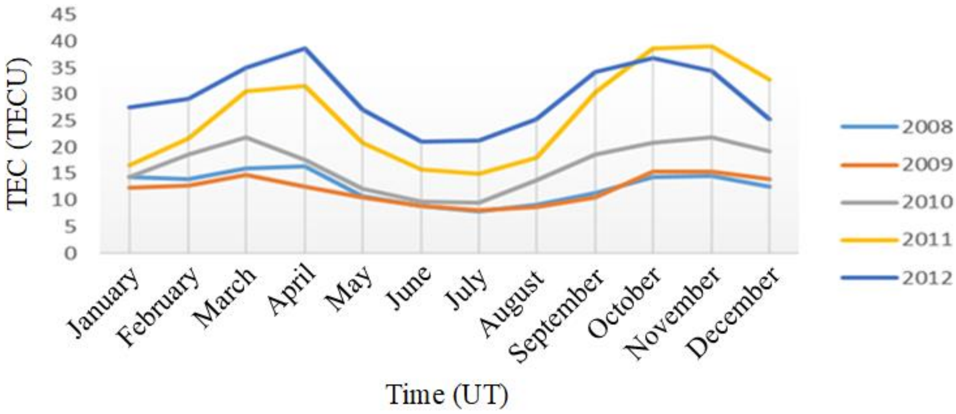

Figure 6. Annual TEC data value (2008 – 2012).

4. CONCLUSION

The minimum average TEC value occurred in 2009 with a value of 12.00182 TECU and the minimum average TEC value occurred in July with a value of 12.31583 TECU. The maximum average TEC value occurred in 2012 with a value of 29.68622 TECU and the maximum average TEC value occurred in October with a value of 25.253 TECU. The movement pattern of TEC values in observations over five years from 2008 to 2012 experienced almost the same pattern. The minimum average EUV value occurred in 2008 with a value of 18.15136 Watts/m² and the minimum average EUV value occurred in February with a value of 22.57192 Watts/m². The maximum average EUV value occurred in 2012 with a value of 31.46511 Watts/m² and the maximum average EUV value occurred in November with a value of 26.03274 Watts/m². The movement pattern of EUV values in observations over five years from 2008 to 2012 experienced different patterns. The comparison of the correlation between TEC and EUV is directly proportional, where the higher the EUV value, the higher the TEC value and it is influenced by solar activity during the period 2008 – 2012.

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