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Analysis of Total Electron Content (TEC) Near Real Time Using Dual Frequency GPS Data (Study Case: Surabaya)

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Abstract. Ionosphere is part of the atmospheric layer located between 50 to 1000 km above the earth's surface which consists of electrons that can influence the propagation of electromagnetic waves in the form of additional time in signal propagation, this depends on Total Electron Content (TEC) in the ionosphere and frequency GPS signal. In high positioning precision with GPS, the effect of the ionosphere must be estimated so that ionospheric correction can be determined to eliminate the influence of the ionosphere on GPS observation. Determination of ionospheric correction can be done by calculating the TEC value using dual frequency GPS data from reference stations or models. In making the TEC model, a polynomial function is used for certain hours. The processing results show that the maximum TEC value occurs at noon at 2:00 p.m. WIB for February 13, 2018 with a value of 35,510 TECU and the minimum TEC value occurs in the morning at 05.00 WIB for February 7, 2018 with a value of 2,138 TECU. The TEC model spatially shows the red color in the area of Surabaya and its surroundings for the highest TEC values during the day around 13.00 WIB to 16.00 WIB.

Keywords: Ionosfer, TEC, TEC Model

1 Preface

Ionosphere is part of the atmosphere layer which is located between 50 to 1000 km above the earth's surface. Ionospheres contain electrons that can affect the propagation of electromagnetic waves in the form of additional travel time in signal propagation, this depends on Total Electron Content (TEC) in the ionosphere and GPS signal frequency.

The biggest ionospheric effect is on the speed of the signal, which will directly affect the value of the distance from the observer to the satellite. The ionosphere will slow down the pseudorange (the size of the distance becomes longer) and accelerate the phase (the size of the distance becomes shorter), with the same distance bias (in length units). The magnitude of the distance bias is because the ionospheric effect will depend on the concentration of electrons along the signal path and the frequency of the signal in question. While the concentration of electrons alone will depend on several factors, especially solar activity and the earth's magnetic field.

TEC is the number of electrons in a 1m2 cross section of vertical (cylindrical) columns along the signal path in the ionosphere. the effect of TEC on signals is the signal from GPS satellites that through the ionosphere will experience a delay time because it is affected by free electrons in the ionosphere.

The ionosphere is an important source of distance and range error values for Global Positioning System (GPS) users who require high accuracy measurements. Determination of ionospheric correction can be done by calculating the TEC value using dual frequency GPS data from reference stations or models.

In this research, the analysis of the ionospheric TEC value in Surabaya in near real time is carried out using the daily TEC computation method of two frequency GPS data and spatial TEC depictions are carried out in Surabaya and its surroundings. This is done to provide information on the characteristics of the TEC in Surabaya in near real time

2 Method

The location of the study was located in the Surabaya area at coordinates 07º 09 '- 07º 21' LS and 112º 36 '- 112º 54' BT.

Fig. 1. Research Location (BIG, 2017)

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Perform data processing RINEX format observation uses the rdrnx.f program to get the time and value of the STEC value from the observation station. Determination of the STEC value in accordance with the satellite that has an orbit within the territory of Indonesia where the results are adjusted to the IPP data that has been determined. In STEC calculations also carried out correction of satellite bias, receiver bias. In determining the STEC value obtained by the formula:

$$STEC = TEC_{observasi} - bias_{satelit} - bias_{receiver} \quad (1)$$

The satellite orbit position that has been obtained from processing using the rdeph.f program on the Gfortran application then continues processing to determine the position of Ionospheric Pierce Points (IPP) using the Matlab application. From the position of Ionospheric Pierce Point (IPP) that has been obtained, the location at the ionospheric point can be known.

VTEC calculation for the mapping function to get the VTEC value in the Surabaya area, with the formula:

$$\begin{bmatrix} STEC^1 \\ STEC^2 \\ \cdots \\ STEC^n \end{bmatrix}^T = [a_0 + a_1 + a_3 + b_1 + b_2] \cdot \begin{bmatrix} m^1 & m^2 & & m^n \\ m^1\theta^1 & m^1\theta^1 & & m^n\theta^1 \\ m^1\theta^{1^2} & m^1\theta^{1^2} & & m^n\theta^2 \\ m^1\theta^{1^3} & m^1\theta^{1^3} & \cdots & m^n\theta^3 \\ m^1\lambda^1 & m^1\lambda^1 & & m^n\lambda^1 \\ m^1\lambda^{1^2} & m^1\lambda^{1^2} & & m^n\lambda^2 \end{bmatrix} \quad (2)$$

$$VTEC = a_0 + a_1\theta^1 + a_2\theta^2 + a_3\theta^3 + b_1\lambda^1 + b_2\lambda^2 \quad (3)$$

The description of the VTEC model is done by limiting the Surabaya area and its surroundings by presenting a table of corresponding VTEC values of the VTEC value that has been obtained.

The analysis is carried out on the graph of changes in the TEC value and the characteristics of the TEC values in daily. As well as an analysis of the model of the VTEC value of the Surabaya area and its surroundings.

3 Analysis and Discussion

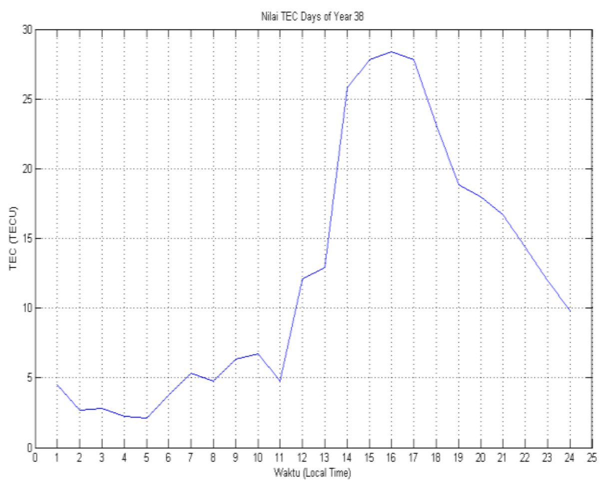

Fig. 2. TEC Value Chart for First Day

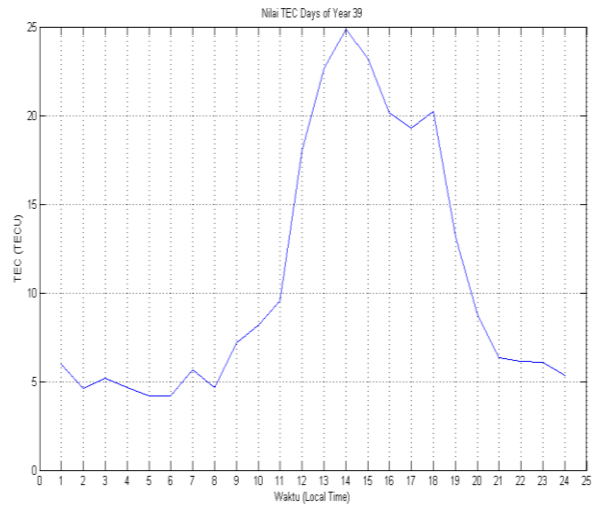

Fig. 3. TEC Value Chart for Second Day

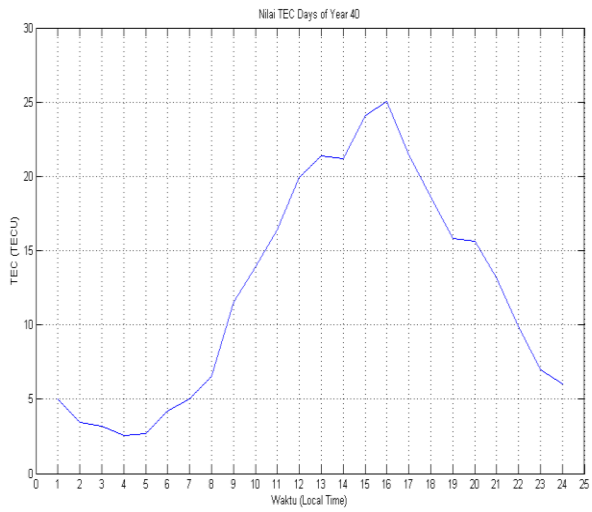

Fig. 4. TEC Value Chart for Third Day

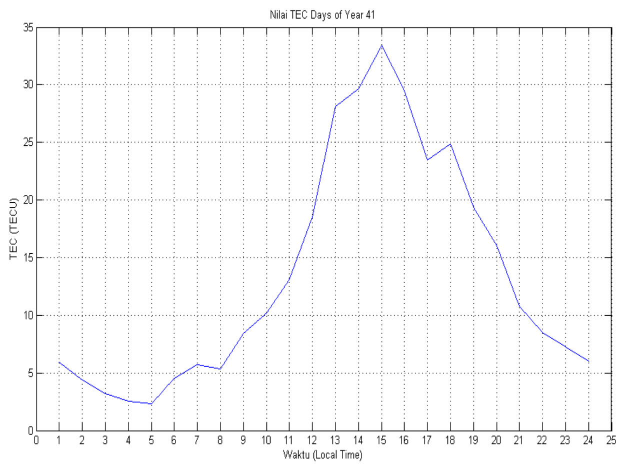

Fig. 5. TEC Value Chart for Fourth Day

Based on Figure 2 to Figure 8, the TEC value is obtained for the maximum and minimum values on 7 February 2018 to 13 February 2018 with the details in the table 3.

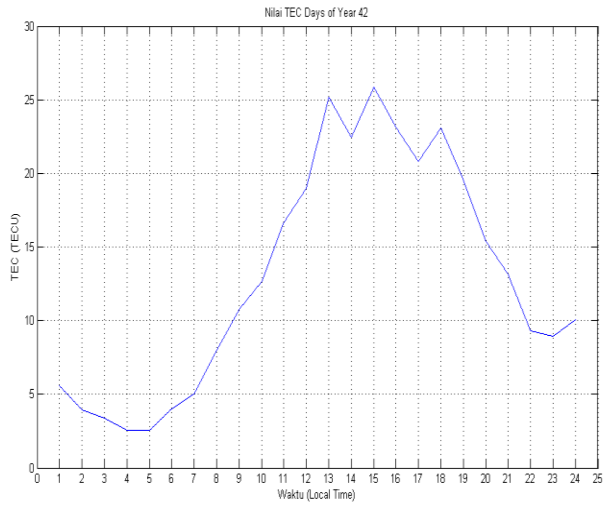

Fig. 6. TEC Value Chart for Fifth Day

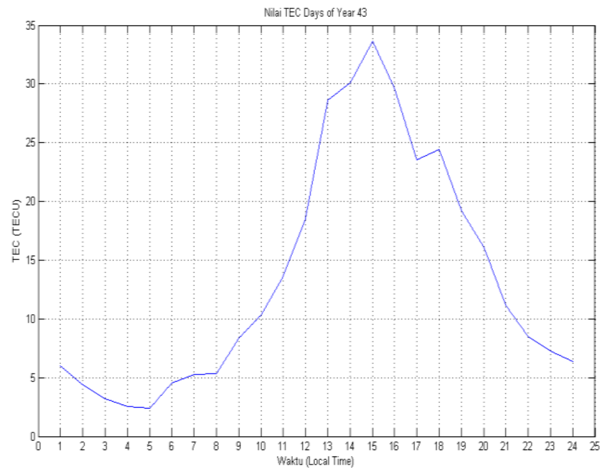

Fig. 7. TEC Value Chart for Sixth Day

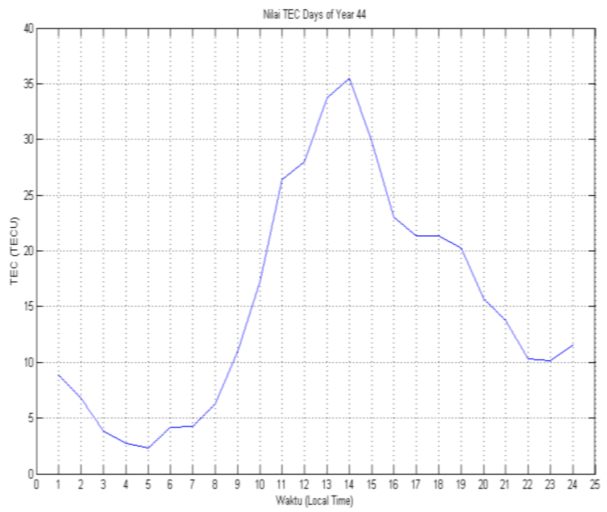

Fig. 8. TEC Value Chart for Sevent Day

Based on the TEC values obtained, shows that the TEC value has increased during the day where this is caused by the influence of the sun which causes the number of electrons to increase. While the minimum TEC value occurs at night due to weak solar activity so that the number of electrons weakens.

Table 3. Maximum and Minimum TEC values on 7 February 2018 to 13 February 2018

Date	O'clock	Value ofTEC (TECU)
7 Februari 2018	16.00 WIB	28,394
	05.00 WIB	2,138
8 Februari 2018	14.00 WIB	24,889
	05.00 WIB	4,166
9 Februari 2018	16.00 WIB	25,031
	04.00 WIB	2,552
10 Februari 2018	13.00 WIB	33,395
	05.00 WIB	2,337
11 Februari 2018	15.00 WIB	25,880
	04.00 WIB	2,529
12 Februari 2018	15.00 WIB	33,636
	05.00 WIB	2,400
13 Februari 2018	14.00 WIB	35,510
	05.00 WIB	2,319

3.1. Analysis of the Total Value Front Content (TEC) Model of the TEC Value Model at 2:00 p.m.

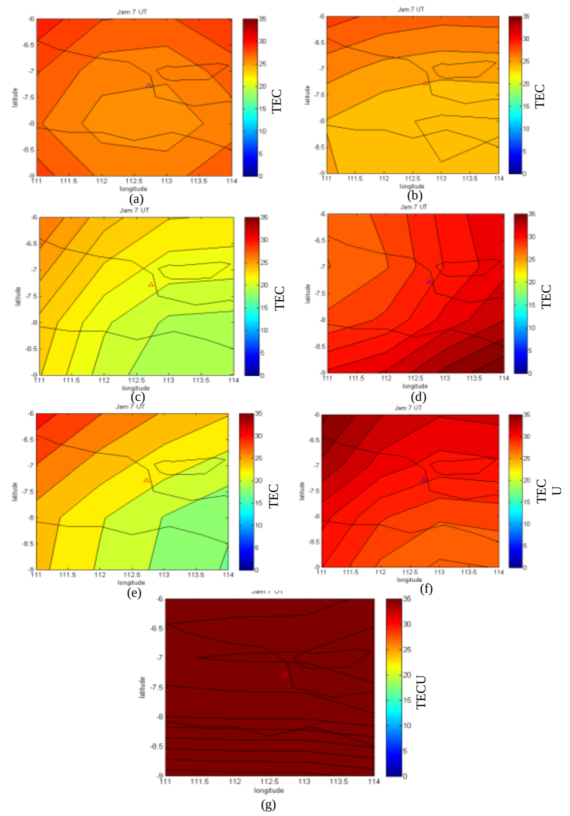

Fig. 9. TEC Value Model at 14.00 WIB (02.00 pm)

In Figure 9 is a TEC model for 14.00 WIB from 7 February 2018 to 13 February 2018. It is known that the largest TEC value occurred on 13 February 2018 so that the 9g area of Surabaya and its surroundings is red. For figures 9a to 9f experience a state of increasing the value of TEC so that the Surabaya area and its surroundings experience a change to red.

4 Conclusion

Based on data processing and analysis conducted, the authors can draw conclusions in this study as follows:

1. The maximum TEC value occurs on February 13, 2018 with a value of 35,510 TECU at 14.00 WIB. While the minimum TEC value occurs on 7 February 2018 with a value of 2,138 TECU at 5.00 WIB.
2. The Model TEC movement for 14.00 WIB shows a high TEC value, this can be seen in the red area of Surabaya and its surroundings.

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