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Research Article

COMPARISON OF REGIONAL AND GLOBAL TEC VALUES: TURKEY MODEL

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ABSTRACT: The ionosphere is a layer of atmosphere 60 km to 1100 km above the earth and is composed of solar rays and ionized gases. The ionosphere is an important layer affecting Global Navigation Satellite System (GNSS) measures. The quality of GNSS measures is directly related to the changes in the ionosphere. For this reason, monitoring changes in the ionosphere is quite important. One of the important parameters expressing the characteristic of the ionosphere is the Total Electron Content (TEC), which is a function of electron density exhibiting transformation with solar radiation.

In this study, 68 stations including 56 Continuously Operating Reference Stations-Turkey (CORS-TR) stations and also IGS stations were taken for evaluation. Bernese v5.2 GNSS software developed by Bern University of Switzerland was employed at the evaluation stage. From 2009 until 2015, TEC values were calculated at two hourly intervals, one day for each month. In the study, where a Single Layer Model was used, TEC values obtained from GNSS measurements have been compared with the TEC (IRI-2012 TEC) values obtained from the global ionosphere map (GIM-TEC) and the international ionosphere reference model programme published by the Centre for Orbit Determination in Europe (CODE), the European Space Agency (ESA), and the Jet Propulsion Laboratory (JPL). As a result, the regional (RIM) TEC values and the global (CODE, ESA, JPL) TEC values showed a large similarity, and the IRI obtained TEC values remained lower than these four values was observed. Correlation coefficient was calculated to determine the relationship between regional TEC values obtained after the evaluation and global TEC values. There is a positive and quite high correlation between the regional (RIM) TEC values produced by the calculated correlation coefficients and the global (CODE, ESA, JPL) TEC and IRI TEC values.

Keywords: *GNSS, Total Electron Content (TEC), Ionosphere, Global Ionosphere Map (GIM)*

1. INTRODUCTION

With respect to the signal propagation, the atmosphere is subdivided into two main layers of the troposphere (also referred to as neutral atmosphere) and ionosphere (Memarzadeh, 2009). The troposphere has refraction effect and causes similar effects on both code and phase modulation and results in a delay of up to 30 meters for a horizontal path. Therefore, the effect of the troposphere is considered one of the major sources of errors imposed on the satellite signals. On the other hand, the ionosphere having a dispersing effect among ionized atmosphere layer(s) affects the signal code and phase modulation in an opposing way (Başpınar, 2012; Basciftci etal, 2017b). The troposphere usually covers a region being up to 40 km from the sea surface, and the ionosphere covers about 60 km to 1000 km and even more.

Monitoring the ionosphere is important for mainly GNSS (Global Navigation Satellite System) and for study areas like communication, security, navigation as well. Changes in ionosphere effect satellite based studies directly. GNSS receivers are widely used in studies related ionosphere because they spread most of the world and the information (Total Electron Content, TEC) about ionosphere can be obtained from satellites monitored by these receivers. (Alçay et al., 2014).

The purpose of this study is to determine TEC values by benefiting IGS stations which have uninterrupted data between the years 2009-2015 were determined by using the data evenly distributed CORS-TR stations in order to modelling ionosphere in high sensitivity and resolution in Turkey, comparing the regional TEC values with global TEC values, determining the correlation coefficients to find out the relationship between regional TEC values with global TEC values. In this scope Bernese v5.2 GNSS software was used to determine the regional TEC values.

2. IONOSPHERE

Total Electron Content (TEC) used in expressing the general behaviour and structure of the ionosphere can be determined by GNSS. When it is thought that GNSS satellites are 20200 km above the earth, the signal sent from a satellite completely passes through the ionosphere layer and gives an advantage in understanding the structure of the entire ionosphere. Another advantage is that GNSS satellites make it possible to constantly monitor the ionosphere by transmitting uninterrupted signals (Inyurt, 2015).

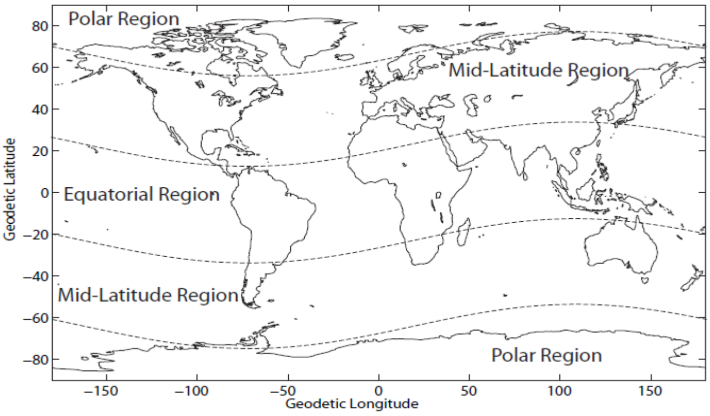
The ionosphere is contained within a region between 60 km to 1100 km from Earth. This layer is the ionized part of the atmosphere and consists of free electrons and positively charged ions. The electrical properties of signal propagation and the environment are influenced by these particles (Hugentobler et al., 2001, Hunsucker and Hargreaves, 2003).

The ionosphere layer can be thought of as that part of the world between the neutral atmosphere and the atmosphere completely ionized by the Sun. In the neutral layer, while the wave propagation in the ionosphere is being affected by the number of electrons available in the form of free electrons along the path of a wave, the propagation of waves in the ionosphere mainly depends on factors such as pressure, temperature and water vapour content. A large number of free electrons and ions emerge as a result of radiation from the Sun which hits molecules and atoms in the air. In fact, what determines the maximum and minimum height of the ionosphere layer is this ionization. The amount of electrons within a 1 m^2 based cylinder along the line between the receiver and the electromagnetic signal is called TEC (Total Electron Content) and is expressed in TECU units. 1 TECU = 10^{16} electron / m^2 (Schaer 1999; Abdullah et al, 2009; Dach et al, 2015; Basciftci et al, 2017a). The single layer model (SLM) is an approach used to model the total electron density. This model assumes that all free electrons are compressed into a very thin layer at H height above the Earth's surface (Wild, 1994). TEC varies according to the time of day, season, solar cycle, geographical location of GNSS receiver and the magnetic field of the Earth (Warnant and Pottiaux, 2000).

In general terms, the complex structure of the ionosphere emerges as the most important obstacle in GNSS positioning. GNSS signals are affected by electrons on the path they follow until arriving at the receiver. The correction to be brought to this effect reaches its maximum values in the months of the equinox and in the winter months (March, April, September, October), and minimum values in the summer months (Kahveci, 1997) While the effect demonstrated by the ionosphere during the night is 10 nano seconds (about 3 m) it reaches up to 50 nano seconds (about 15 m) during daytime (Klobuchar 1987). While the ionosphere layer reflects frequencies below 30 MHz, it affects the high - frequency radio-waves (Klobuchar 1991).

2.1 The Structure of the Ionosphere

The ionosphere is divided geographically into three major regions: the high latitude region, the middle latitude region and the equatorial region (Figure 1a). These regions are taken as the base in scientific studies. The high latitude region between 55-90 latitudes is divided into two as the auroral and polar regions. The area covering the 55-67 latitudes represents the auroral region (Datta-Barua 2008). The ionospheric delay is lower due to the ultraviolet (UV) rays showing a low ionization tendency in this region during daytime. The polar region is located at upper latitudes of the auroral region. At these latitudes, the dense electron groups are formed as 50 – 1000 km long clusters. These dense electron clusters are located at the F2 layer and the scintillations occur in this region. The TEC value in this region is low, but the sudden changes occurring in the range generally prevent determination of the overall behaviour of TEC. Ionization in this region realizes as a result of both the Sun's rays and inter-particle collisions. The mid latitude region located between latitudes 20-55, in which Turkey is also found, is the region where TEC changes happen least. Few occurrences of change ensure advantages in terms of overall behaviour of electron quantity to be known, and the change usually emanates from X-rays and ultraviolet rays. The reason why devices and equipment that observe ionospheric changes are found here, is that a major part of countries that conduct studies are located in the middle latitude region (Arslan 2004), while the equatorial region is the region where the total electron quantity change happens most. In particular, changes in certain sections of the equatorial region are twice as likely than in the middle latitude region. The decrease in the number of electrons occurs due to reasons like magnetic storms and earthquakes, and can be expressed as an Appleton anomaly. This anomaly reaches its maximum level at 14:00 local time (Gizawy, 2003), also, in this region, as with the high latitude region, it is quite difficult to determine a general TEC behaviour.



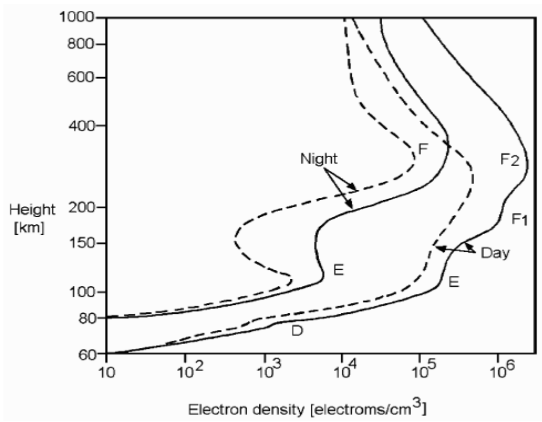


Figure 1. a) Ionosphere regions (Memarzadeh, 2009) b) Ionosphere layers (Hargreaves, 1992)

The ionosphere layer consists of 4 different layers; D, E, F1 and F2 (Figure 1b). Each of these layers, caused by the severity of ionization, behaves differently during the day. Layer D is between 60 km and 90 km. It occurs under the influence of strong X-rays. It also contains neutral atoms as well as free atoms (Tileylioglu 2007). It is considered that this layer does not have significant effects on GNSS measurements. Long waves are reflected from this layer back to Earth. The layer between 90 km and 140 km is called Layer E. This layer has been formed by the effect of weak X-rays. The effect of the layer is minor in comparison to GNSS measurements. Partial ionization occurs frequently at Layer E. This event is called irregular E. This ionization is not thought to be related to Layer E during daytime. The anomaly caused by the effect of sunlight at this layer causes the deflagration in the arctic region (Arslan 2004). Medium and short wavelengths are reflected from this layer back to Earth.

The layer covering approximately 140-200 km is called Layer F1. The effect of this layer combined with Layer E is 10% on GNSS signals. Propagation at F1 layer is not significant, but it has a predictable electron density. The F2 layer is the region where the anomalies are most dominant in terms of electron density, while its effect on the GNSS measure is rather high (Arslan 2004). The maximum range of electron density at the F2 layer covering about 200-1000 km varies between 250-400 km. This value may vary with factors such as magnetic storms, night time and equatorial zone (Petrie et al. 2011).

Medium and short wavelengths are reflected from this layer back to Earth. While the layers D, E and F1 form the middle part of the ionosphere, F2 and above form the upper part of the ionosphere.

Since the ionosphere is a scattering medium, TEC values can be determined with the assistance of L1 and L2 carrier signals sent from GNSS satellites. TEC values contain information on global or regional ionosphere structure (Fedrizzi et al., 2001, Davies and Hartmann, 1997).

The local (regional) TEC map is obtained by applying the Taylor expansion to the L4 linear combination equal to the difference between L1 and L2 phase measurements.

$$L4 = L1 - L2 \tag{1}$$

To model the effects of the global ionosphere, the spherical harmonic expansion is used because the Taylor expansion in the regional quality remains insufficient. Global TEC maps created at 5 different centres are available in IONEX format (URL 1) and the global TEC model can also be obtained with Bernese GNSS software (Arslan, 2004).

Changes of the TEC in the ionosphere may be determined by GNSS observations before, during and after earthquakes (Ulukavak and Yalçınkaya, 2014). Electrical and magnetic field changes may occur in an earthquake area and its vicinity due to earthquakes. As these changes proceed to the atmosphere, the electron density of the ionosphere changes due to the uniting of the neutral atmosphere and ionized plasma (coupling) (Calais et al., 1998). Before large volcanic eruptions, the rate of occurrence of TEC anomalies are related to volcanic type and geographical location (Li et al., 2016). Thus, the effects of earthquakes and volcanic eruptions may be monitored (Basciftci et al, 2017b).

3. IONOSPHERIC MODELS PRESENTED BY THE INTERNATIONAL GNSS SERVICE (IGS)

Many institutions across the world produce a global ionospheric TEC map (GIM). These institutions are:

ESA / ESOC (European Space Operations Centre, Germany), JPL (Jet Propulsion Laboratory, California), NOAA (National Oceanic and Atmospheric Office, USA), CODE (Centre for Orbit Determination in Europe, Switzerland), DLR (Fernerkundungstation Neustrelitz, Germany), NRCan (Natural Resources, Canada), ROB (Belgium Royal Observatory, Belgium), UNB (New Brunswick University, Canada), and UPC (Catalan Polytechnic University) (Schaer, 1999; Basciftci et al, 2017b). A global ionosphere map (GIM) is published in IONEX (IONosphere map EXchange) format. TEC data in IONEX format are arranged to cover the whole world. The desired TEC value can be obtained from this sequence. If the latitude and longitude of a point are known, the TEC value is obtained for the nearest 4 TEC values that incorporate two variable interpolation points (Schaer et al., 1998). When the value calculated to determine the TEC in the TECU unit is multiplied by 0.1, the TEC value of the relevant point is determined in TECU units. IONEX – formatted global ionosphere maps are produced in 2-hour intervals. For TEC values, the increase in the longitude is 5° and the increase in the latitude is 2.5° (Arslan, 2004). The accuracy of TEC values published in IONEX format varies between 2-8 TECU. In recent years, studies using ionospheric models of CODE, ESA, JPL and IRI have been widely used (Gao et al, 2002; Liu et al, 2005; Mao et al, 2008; Liu et al, 2009; Hernández-Pajares et al, 2009; Scharroo and Smith, 2010; Ya'acob et al, 2010; Wan et al, 2012; Bilitza et al, 2014; Leong et al, 2015).

Using the data from approximately 200 GPS stations of CODE, Bern University, Switzerland: CODE Global Ionospheric Maps (GIMs), IGS and other institutions, the CODE Global Ionospheric Maps (GIM) are produced on a daily basis. Up to 15 degrees, Vertical Total Electron Content (VTEC) has been modelled using a spherical harmonic expansion in the solar-geomagnetic reference framework.

ESA, Darmstadt, Germany: VTEC values are determined by vertical integration onto the Chapman Profiler model using the carrier phase level for cosz and code observables as a mapping function.

JPL, Pasadena, United States of America: Vertical TEC (VTEC) has been modelled on a solar – geomagnetic reference plane using a bi – cubic spline on a spherical grid. The Kalman filter is used on the grid to solve VTEC and instrumental biases at the same time (such as the stochastic parameters).

The IRI model has been produced in collaboration with the International Union of Radio Science (URSI) and the COmittee on SPAce Research (COSPAR), and has been periodically developed and improved. The latest version of the model is IRI-2012 (Bilitza et al, 2014). IRI can provide a lot of parameters related to the ionosphere, including the TEC value for ionospheric heights between 60 km and 2,000 km depending on location, date and time (Leong et al, 2015). Thanks to the IRI-2012 programme, TEC values (URL 2) can be calculated online from the internet address together with the latitude and longitude values of the corresponding day. The model makes calculations over six different parameters: electron density, electron temperature, ion content, ion temperature, ion drag and total electron content (Inyurt, 2015).

Solutions can be downloaded from the page of the IGS data centre (URL 1). Until now, no inconsistencies have emerged in the solutions published by different analysis centres.

4. DETERMINATION OF A REGIONAL IONOSPHERE MODEL (RIM) WITH BERNESE GNSS SOFTWARE

A regional ionospheric model with high accuracy can be determined using Bernese GNSS software (Todorova et al, 2003) by calculating VTEC values from specific points without the need for interpolation.

Prior to activating the program in the flow chart in Figure 2, the following files, which are updated from time to time by the Bern University Astronomy Institute, must be introduced to the program. These files are required to be consolidated under C: \ BERN52 \ GPS \ GEN folder (URL3).

COST	DATUM
EGM2008_SMALL	GPSUTC IO8.ATX
IAU2000R06.NUT	IERS2010XY.SUB
IONEX	IONEX.PPP
OT_FES2004.T10	PCV.I08
POLOFF	RECEIVER
s1_s2_def_ce.dat	SATELLIT.I08
SINEX	SINEX.PPP
SINEX.RNX2SNX	TIDE2000.TPO

Before the program is run, the satellite problem file (SATyyyy.CRX) belonging to year of resolution should be placed in C: \ BERN52 \ GPS \ GEN folder (URL3).

The DATAPOOL folder where the raw data belonging to the day when the solution will be performed is filled in. Under this scope, the following files should be found under this index:

- In the index of BSW52; CODwwwwd.TRO, CODwwwwd.ION, P1C1yymm.DCB, P1P2yymm.DCB, P1P2yymm_ALL.DCB (URL3)
- In the index of COD; CODwwwwd.CLK, CODwwwwd.EPH, CODwwww7.ERP, CODwwww7.SNX, CODwwww7.SUM (URL3)
- In the index of IGS; iglwwwwd.sp3, iglwwww7.sum, igswwwwd.clk, igswwwwd.sp3, igswwww7.erp, igswwww7.sum (URL1)
- In the index of REF52; *.CRD, *.VEL, *.STA, *.PLD, *.ABB, *.ATL (to be created with the Bernese program based on .CRD file), *.BLQ (URL4) with .CRD from internet address), IGS.FIX, IGS08_R.CRD, IGS08_R.VEL (URL3)
- In the index of RINEX; there must be 24–hour raw data of the stations which are going to be solved and taken as a reference.
- In the index of VMF1; VMFG_yyyymmdd.H00, VMFG_yyyymmdd.H06, VMFG_yyyymmdd.H12, VMFG_yyyymmdd.H18, VMFG_yyyymm(dd+1).H00 (URL5)

Then, the relevant campaign (session) needs to be defined for the day to be resolved in the program. The following process steps are performed in defining the relevant session.

BERNESE >> Campaign >> Edit list of campaign

BERNESE >> Campaign >> Select active campaign
BERNESE >> Campaign >> Create new campaign

At this stage, the time of data to be solved is introduced into the program. In definition of time to the program at this section, entering either one of the information for Year-Month-Day / Modified Julian day / GPS week-day of the week or Year - day of year. The process step to be followed in this step is;

BERNESE >> Configure >> Set session/compute date

To prepare and define the solution time for the data to be solved at this stage, the automatic solution starts with;

BERNESE >> BPE>> Start BPE processing >> PPP_DEMO.PCF

If no error message is encountered at the end of activating the program, TEC values pertaining to the day related to the RIMwwwwd.INX file under the campaign folder whose solution is being actualized in the ATM index or under SAVEDISK >> PPP >> YEAR >> ATM folder are obtained.

In the evaluation, an automatic process was performed using the Bernese v5.2 GNSS software ready command PPP_DEMO.PCF and regional TEC values (RIM * .INX) were obtained.

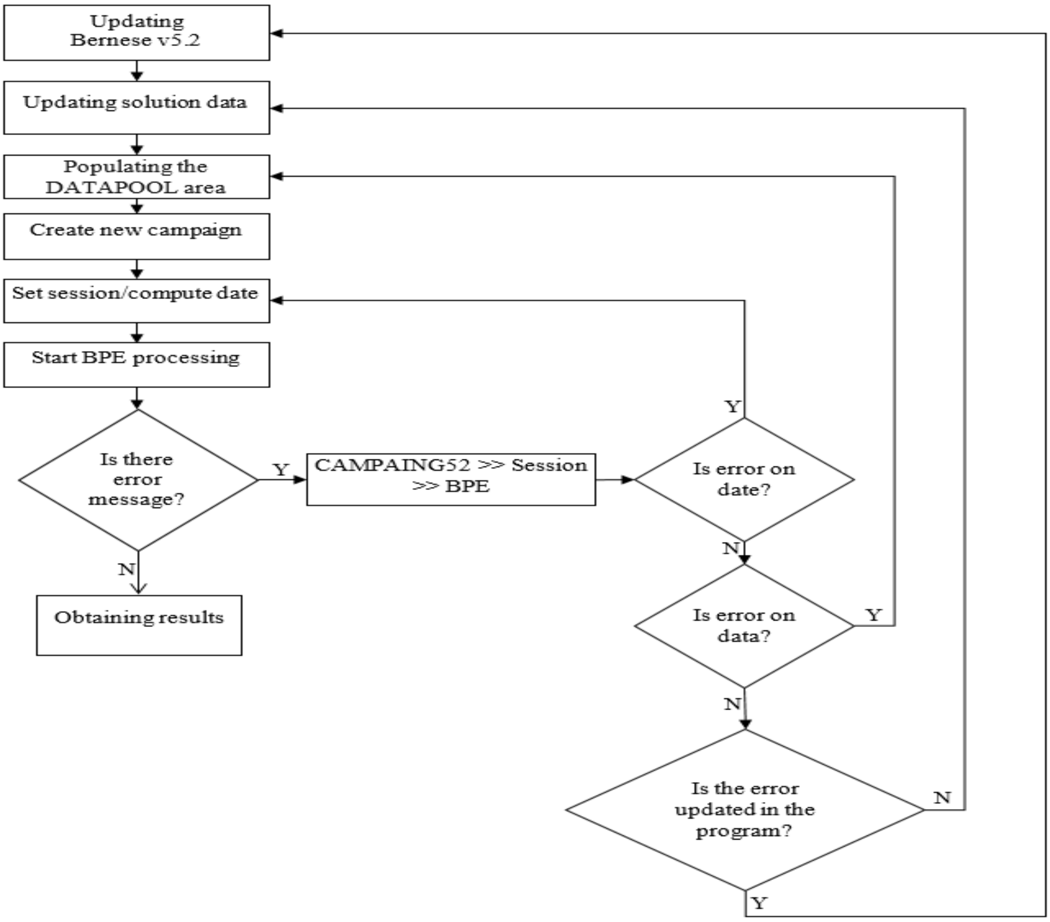


Figure 2. Workflow diagram for obtaining TEC values in Bernese v5.2 GNSS software

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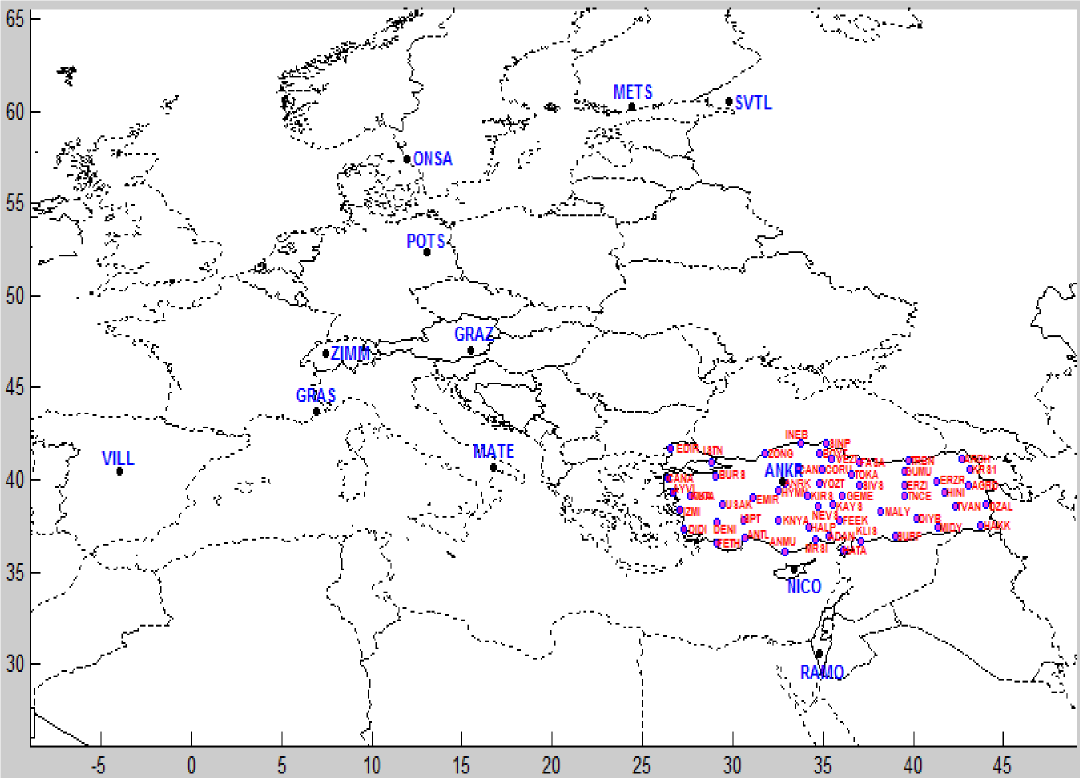

Figure 3. GNSS network used in the study

5. APPLICATION

In this study, TEC values for Turkey from 2009 to 2015 are calculated. The regional TEC model has been used in the assessments made using Bernese v5.2 GNSS software. In the study where the single – layer model was employed, the height has been taken as 450 km. The height of the ionosphere is accepted as 450 km by softwares and it is assumed that TEC being at this height is at its highest value. In order for the produced TEC values to be compared, the GIM values produced by CODE, ESA and JPL, and the IRI-2012 model developed by COSPAR and URSI have been used.

CORS-TR and IGS stations used in the analysis are shown in Figure 3. In the study, where a total of 68 stations were used, 56 of them are CORS-TR stations and others are IGS stations. The data for the CORS-TR stations have been obtained from the address URL 6 and the data pertaining to IGS stations from URL 7. The TEC values obtained as a result of the evaluation are plotted by MATLAB R2014a. As a result of the analysis, regional TEC values have been obtained from 2009 until 2015. To compare the regional TEC values obtained from the GNSS software with Bernese v5.2 GNSS, GIM-TEC values published by CODE, ESA and JPL, obtained by IRI, have been downloaded from the URL 1 address, and by entering the latitudes and longitudes belonging to the TEC values – related day obtained from IRI, this has been calculated online from the URL 2 address.

As a result of the evaluations, the mean of the TEC values from 2009 until 2015 was calculated and compared with IRI and GIM (JPL, ESA, CODE) mean TEC values (Figure 4-7). Since all of the stations in the study showed similar behaviour, only 4 stations which can be represented Turkey are given as examples.

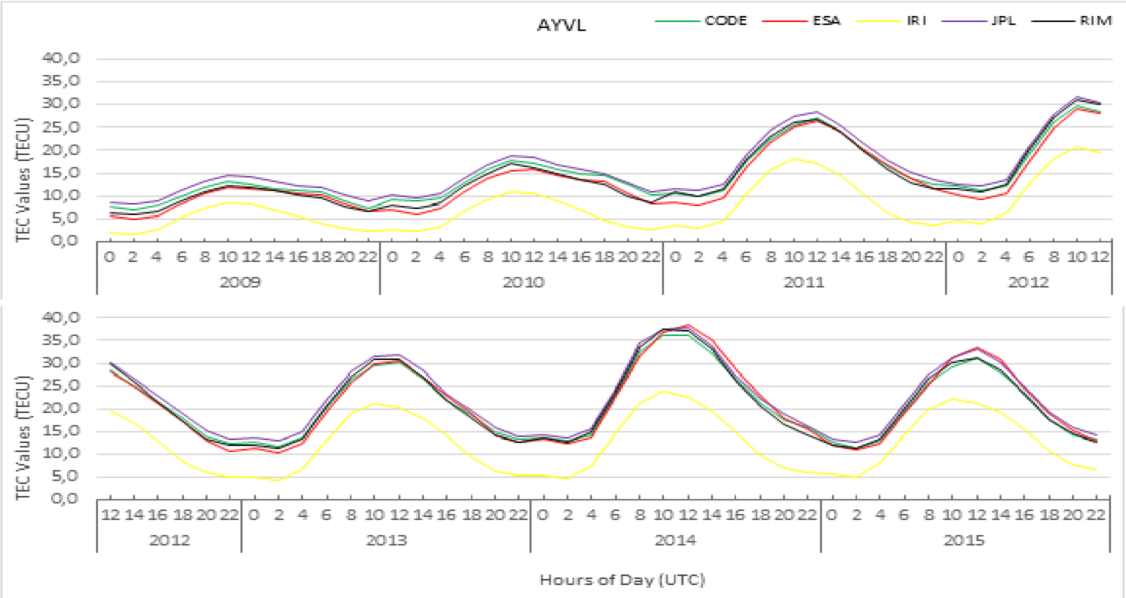

Figure 4 Comparison of average TEC (RIM-Result) values obtained for AYVL station between 2009-2015 with CODE, ESA, JPL, IRI values

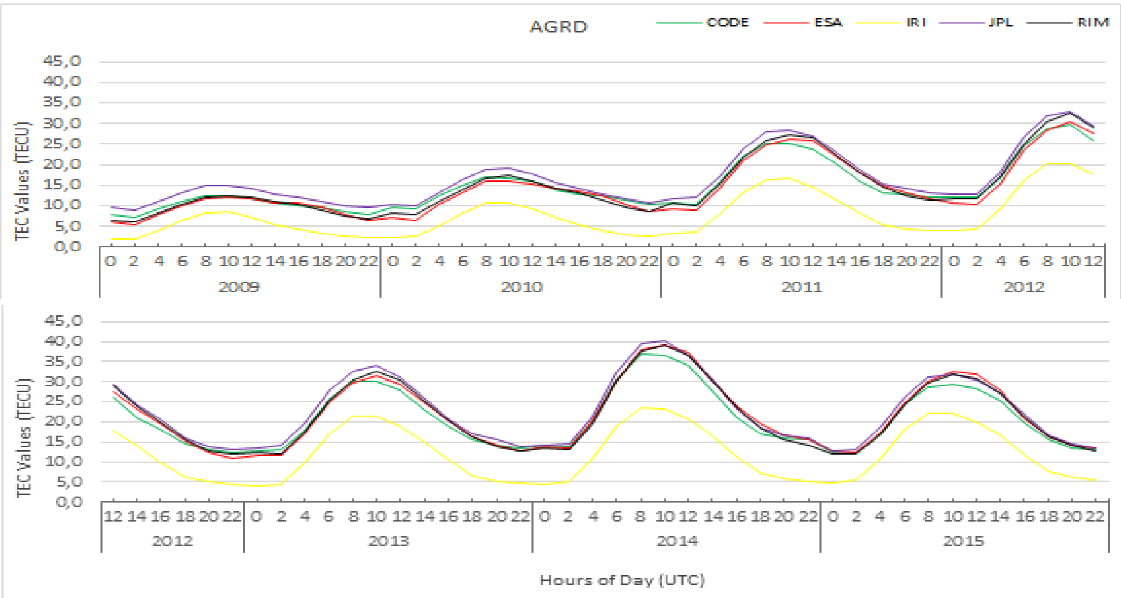

Figure 5. Comparison of average TEC (RIM-Result) values obtained for AGRD station between 2009-2015 with CODE, ESA, JPL, IRI values

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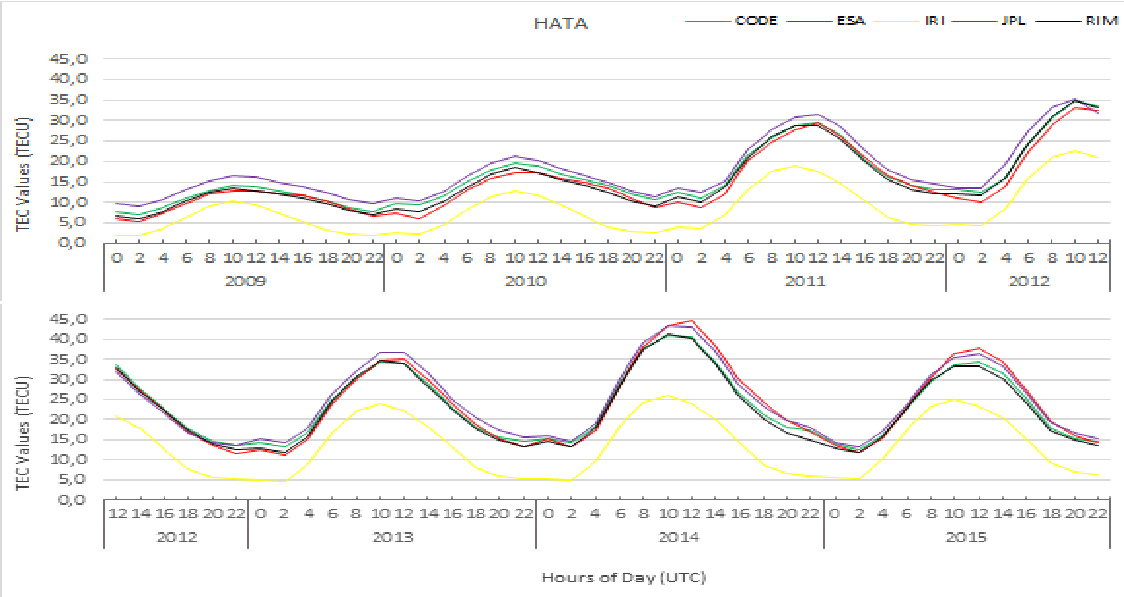

Figure 6 Comparison of average TEC (RIM-Result) values obtained for HATA station between 2009-2015 with CODE, ESA, JPL, IRI values

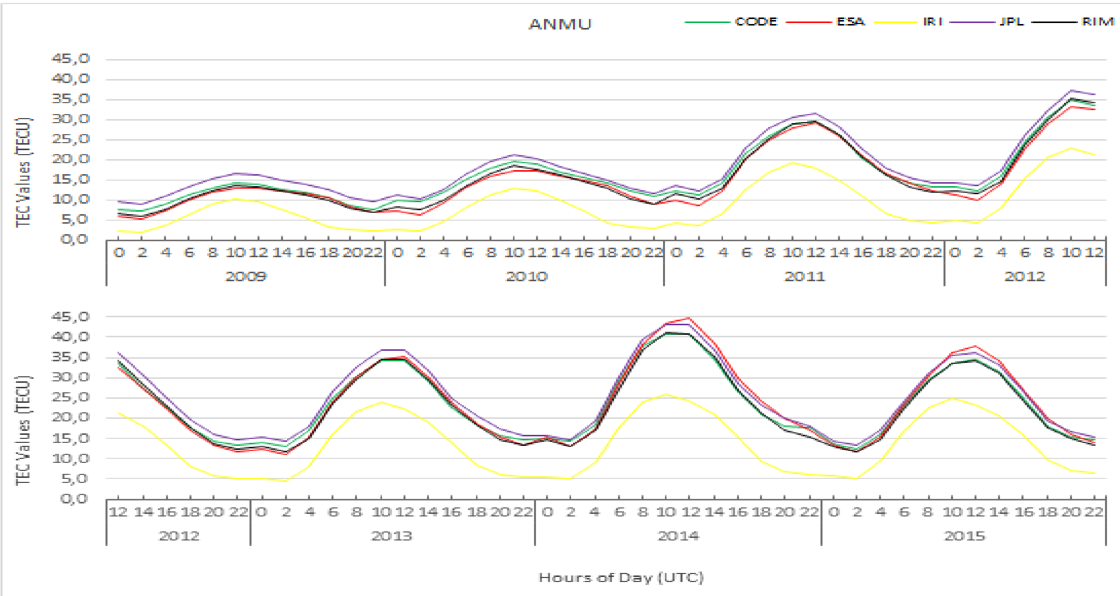

Figure 7. Comparison of average TEC (RIM-Result) values obtained for ANMU station between 2009-2015 with CODE, ESA, JPL, IRI values

The average TEC has been produced by utilization of TEC values estimated in the above figures and they have been compared with the average values between 2009 and 2015.

When Figures 4-7 are considered, the TEC values obtained from the regional ionosphere model (RIM), the global ionosphere model (CODE, ESA, JPL), and the IRI model, have generally been increasing with the regional ionosphere model (RIM) at 02:00, and reached their maximum value at 10:00. This shows that it began to decrease from 12:00, its density was at a minimum value between at 02.00, and at minimum values between 10:00 – 12:00.

Table 1 gives the minimum, maximum and average values of TEC (RIM) values obtained as a result of the evaluation, and TEC values obtained from IRI and Global Models (CODE ESA, JPL) from 2009 to 2015.

As a result of the analysis, to determine the correlation level between regional TEC values and Global (CODE, ESA, JPL) and IRI TEC values, the correlation between the regional and global models from 2009 until 2015 was determined. This is shown in Table 2.

Table 1 Test statistics for regional and global models (TECU)

Test Statistics	Years	Regional	Global (GIM)			
		RIM	CODE	ESA	JPL	IRI
Minimum	2009	5.40	6.93	4.91	8.09	1.63
	2010	6.85	8.81	5.91	9.26	2.05
	2011	9.32	9.59	7.75	11.07	2.68
	2012	1.14	10.80	8.74	11.94	3.74
	2013	10.63	11.42	10.22	12.52	3.90
	2014	11.97	12.55	12.02	13.49	4.37
	2015	10.49	10.88	10.40	12.00	4.62
Maximum	2009	13.40	14.23	12.94	16.62	10.33
	2010	18.63	19.54	17.21	21.37	12.96
	2011	29.67	29.49	29.27	31.59	19.09
	2012	35.22	34.83	33.28	37.12	22.78
	2013	34.84	34.28	35.09	36.84	23.92
	2014	41.29	40.96	44.71	43.27	25.98
	2015	34.24	34.46	37.76	36.33	25.11
Average	2009	9.09	10.08	9.11	11.89	4.78
	2010	12.05	13.42	11.82	14.48	6.09
	2011	17.77	17.72	17.45	19.53	9.25
	2012	19.83	19.53	18.85	21.22	11.27
	2013	20.38	20.44	20.31	22.15	11.86
	2014	24.03	23.98	24.92	25.51	13.05
	2015	20.46	20.31	21.27	21.84	12.97

Table 2 Correlation between regional (RIM) TEC values and global (CODE, ESA, JPL) and IRI from 2009 until 2015

	Years	RIM - CODE	RIM - ESA	RIM - JPL	RIM - IRI
Correlation Among Regional and Global TEC Values	2009	99.3%	98.3%	99.5%	96.3%
	2010	99.2%	97.2%	99.7%	97.5%
	2011	99.6%	98.9%	99.8%	98.7%
	2012	99.8%	99.6%	99.9%	99.5%
	2013	99.8%	99.7%	99.9%	99.3%
	2014	99.7%	99.4%	99.8%	99.0%
	2015	99.9%	99.6%	99.9%	98.3%

It can been seen that the TEC values were close to GIM TEC values obtained from the Global ionosphere map, and are very different to the IRI-2012 TEC values.

6. CONCLUSION

Studies on determining the TEC value have increased in recent years. In this study, TEC values have been obtained from 68 GNSS stations. These include 56 CORS-TR stations that are located in Turkey and 12 IGS stations. Evaluation of GNSS measures was carried out with Bernese v5.2 GNSS software developed by Bern University, Switzerland.

Regional (RIM) TEC values were obtained from 2009 to 2015. The results are compared with the average values of CODE, ESA, JPL published GIM values and IRI-2012 TEC values (Figures 4-7).

The TEC values obtained from the global ionosphere models (CODE, ESA, JPL) begin to increase at 02:00 and they reach their maximum values at 12:00. In general, the global TEC values are at their lowest value at 02:00 and their highest value between 10:00 and 12:00. It was found that the TEC values obtained online in the IRI model are at their lowest value at 02:00 at night, and the highest value at 10:00. In the regional ionosphere model (RIM), the resulting TEC values began to increase at 02:00 and rise to 12:00, as in the global ionospheric models. In general, it is seen that RIM-TEC values are at their lowest value at 02:00, similar to the global TEC values, and at their highest value between 10:00 and 12:00 (Figures 4-7, Table 1).

When the results are examined, there is a great similarity between regional (RIM) TEC values and global (CODE, ESA, JPL) TEC values, and the TEC values obtained from IRI-2012 are lower than the four values. It is generally seen that the five TEC values obtained increased until noon, and then the TEC values decreased due to the recombination of the ions in free state. The reason that the IRI-2012 TEC estimates in

Turkey are lower than the other models may be due to the lack of ionosonde stations.

The minimum, maximum and average TEC values of regional TEC values, global TEC (CODE, ESA, JPL) and IRI TEC values obtained from the end of 2009 until the end of 2015 were determined (Table 1). It is seen that the minimum, maximum and average TEC values determined when examining Figures 4-7, and the TEC values of the points in Table 1 give similar results

When Table 2 is examined, there is a positive and high-level relationship between regional (RIM) TEC values obtained from the results of the analysis, and the global TEC obtained from the URL 1 and URL 2 addresses.

For all the stations that are planned to be used in Turkey, especially the CORS-TR stations, it is necessary to establish a system that will continuously monitor changes in the TEC value which is the most important function of the ionosphere and to increase the positional accuracy and to studies about earthquake, volcanic eruptions, determining the location of the missile will be an important contribution to their work.

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