Automatic Data Downloading Program (DDP) in Determining Regional Ionosphere Model Data Downloading Program For Bernese v5.2

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ABSTRACT: GNSS (Global Navigation Satellite System) signals pass through various layers of the atmosphere until they reach the receiver on the Earth. One of these layers is the Ionosphere. Ionosphere may be defined as the atmospheric layer that consists of the gasses that are ionized with sunrays located 60 and 1100 km above the ground level with important effects on the signals used by satellite-based positioning, short-wave communication, and other communication systems. One of the important parameters that express the characteristics of the Ionosphere is the Total Electron Content (TEC), which is a function of the electron density that shows variations with the radiation of the Sun. The TEC value cannot be obtained directly from GNSS measurements; however, it may be predicted with the combinations produced. In the scope of the present study, the Bernese v5.2 GNSS scientific Software that was developed by the Swiss Bern University Astronomy Institute (AIUB) was used in the determination of the TEC values for the Regional Ionosphere model. Before the stage in which the TEC values are determined with the Bernese v5.2 GNSS Software, some files must be downloaded from the Internet in the Bernese format according to GPS day/week and year/the day of year values and copies to the DATAPOOL folder, which is created with the use of the software. For this purpose, it has been ensured that the files in the Bernese format are obtained from the relevant Internet addresses in an automatic manner by using a series of commands with the name Data Downloading Program (DDP) in the MATLAB for the purpose of facilitating the manual data collection process and eliminating other possible difficulties that might appear. The users is saved from negative factors like distractibility, decrease in interest, loss of time because there is visuality in the programme interface. The Regional TEC values are computed with the Bernese v5.2 GNSS Software by using the downloaded files. TEC values which were obtained from GNSS measurements compared with global ionosphere maps produced by CODE, ESA, JPL and IRI-2012 TEC produced by international reference model. It is observed that the Regional TEC values (RIM) and the global TEC values (CODE, ESA, JPL) are in agreement, and the difference between them is maximum at 2.1 TECU. The TEC values obtained from IRI-2012 are lower than the Regional TEC (RIM) values, and the difference between them reaches maximum 14.8 TECU

Keywords: GNSS, Bernese, MATLAB, Total Electron Content (TEC), Ionosphere

1. Introduction

Ionosphere is defined as the atmospheric layer located 60 and 1100 km above the ground level surrounding the globe, and consists of the gasses that are ionized with the sun rays (Arıkan et al. 2003; Turel et al. 2007; Aysezen, 2008). Many studies have been conducted on the structure and behaviors of the Ionosphere (Alizadeh et al. 2011; Namgaladze et al. 2012; Pajares et al. 2011; Petrie et al. 2011; Liu et al. 2009; Withers and Mendillo, 2005; Afraimovich and Astafyeva, 2008; Inyurt et al. 2017; Yildirim et al. 2017). When all these

studies are analyzed, it is understood that Ionosphere is in constant change and is sensitive to certain effects.

In general terms, Ionosphere may show variations according to geographical and geomagnetic position, geomagnetic activity, solar activity, the number of the sunspots, seasonality, local time, nuclear explosions, strong thunders and violent storms, ballistic missile flights, and height (Namgaladze et al. 2012; Wild, 1994; Hawarey and Ayan, 2004).

Ionosphere consists of various layers because the electron density hosted by it is not the same everywhere. These are D, E, F (F1, F2) layers, respectively. The D layer is the closest to the Earth. This layer is located 60-90 km above the ground level. The ionization in this layer is controlled by the Sun. It is accepted that this layer does not have any effects on the GNSS measurements (Wild, 1994). The E Layer is located 90-140 km above the ground level. In normal status of the E Layer, the ionization occurs with solar radiation. The effect of this layer on GNSS is little (Başpınar, 2012). The F Layer contains free electrons more than the other Ionospheric layers, and consists of two sub-layers (F_1 and F_2). 10% of the delay of the GNSS signals in the Ionosphere stems from the F_1 Layer (Parkinson and Spilker, 1966). Its structure is regular, and is controlled with the changes in the Sun, and is located 140-200 km above the ground level. The F_2 Layer has an irregular structure and is located 200-1000 km above the ground level (Wild, 1994). The F_2 Layer is the layer in which the ionization occurs in the highest level. The electron density in this layer changes according to time, season, and sunspots. This is the layer that affects the GNSS computations at the highest level.

Today, signal-based applications have become widespread at an enormous speed, and resolving the complex structure of the Ionosphere has become more important than ever. One of the parameters used to express the status of the Ionosphere is the Total Electron Content (TEC). TEC is an important parameter that provides data on Ionospheric activity. TEC is the total free electron content along a cylinder with a section of 1 m^2, and its unit is TECU (Total Electron Content Unit). 1 TECU is 10^{16} el/m^2 (Yildirim et al. 2016; Schaer, 1999; Abdullah et al. 2009; Dach et al. 2015; Chakraborty et al. 2014; Coley et al. 2014; Rama Rao et al. 2006; Schmidt et al. 2008). TEC ionosonde, which is a function of the Ionosphere, may be determined with various ways such as backscattering radar, TOPEX/Poseidon Satellite. However, in recent years, determining the TEC with GNSS has gained speed. The reason for this is the fact that the GNSS systems are less expensive when compared with the other systems, and these systems enable scientists monitor Ionosphere in a non-stop manner.

It is necessary that the data of the campaign that will be analyzed must be downloaded from the Internet in order to evaluate the GNSS Data in the Bernese v5.2 Academic software. This process is extremely time-consuming and difficult. In the present study, the DATA DOWNLOADING PROGRAM (DDP) has been prepared in the MATLAB programming language in order to eliminate this difficulty. With the help of this program, it has been ensured that the files that are in the Bernese format and that will be used in evaluations are downloaded automatically from the Internet.

2. Material and Methods

The Bernese v5.2 GNSS Scientific Software, which was developed by the Swiss Bern University Astronomy Institute (AIUB), has been used in order to determine the TEC values for the Regional Ionosphere Model. The data of the stations used in the evaluations have been obtained from the IGS and CORS-TR Internet websites. It has been ensured that the

files that are in the Bernese format and that are needed for the evaluations according to GPS day/week and year/the day of year values are obtained from the relevant Internet websites through the **Data Downloading Program (DDP)** code in the **MATLAB.** The TEC values of the Regional Ionosphere Model have been obtained by using the files obtained with the DDP Program in the Bernese v5.2 GNSS Software. In this process, the PPP_DEMO.PCF automatic analysis ready command, which is the extension of PPP basic version that has some additional properties such as high-rate troposphere estimation, producing Ionosphere Model, and pseudo kinematic positioning.

2.1.   Bernese v5.2 GNSS software

Bernese v5.2 GNSS Scientific Software is used in geodesic processes that require high sensitivity such as monitoring the movements of the crust of the earth, establishing the geodesic networks of countries, determining the datum parameters, deformation measurements, and determining the properties Troposphere and Ionosphere. Bernese is a versatile software that meets high quality standards in using GNSS systems. General applications of the software may be listed as follows; fast analysis of small-size single and bipolar-frequency measurements, automatic analysis of stable networks, processing real-time applications, analysis of the data collected from multiple receivers, analysis of GPS and GLONASS Data together, monitoring the Ionosphere and Troposphere, clock estimation and time conversion, orbit determination, and SLR orbit confirmation (URL 8). The data flow philosophy of the Bernese v5.2 GNSS Software may be summarized as shown in Figure 1.

Figure 1. The Dataflow in Bernese v5.2 GNSS Software (Dach ,2015)

In order to perform data analysis in the Bernese v5.2 Software, firstly, the files that are in the Bernese format must be downloaded from the Internet and copied to the DATAPOOL folder that is created with the installation of the software.

2.2.   Data Downloading Program (DDP)

In order to make evaluations, it has been ensured in the scope of the present study that the files needed in the Bernese format according to the year/month/day values are obtained from the Internet automatically through the Data Downloading Program (DDP) written in the MATLAB (Figure 2).

In the interface screen, the Year, Months and the day(s) are entered by the user. According to these data, the GPS day/week and the day of the year values are produced by the program (Figure 3). Then, the files that are needed for the analysis to download must be selected to the COD, GEN, igs/igl, DCB and STA folders. In addition, if there are IGS and EUREF points that will be used in evaluations, the 4-character names of the relevant points must be written in the IGS and EUREF points part.
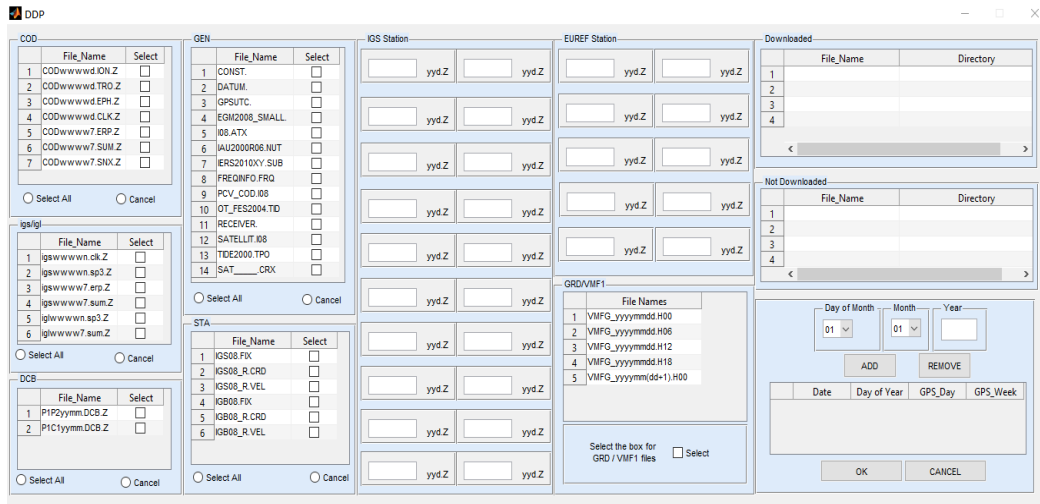
Figure 2. The Interface of the Data Downloading Program (Başçiftçi, 2017)
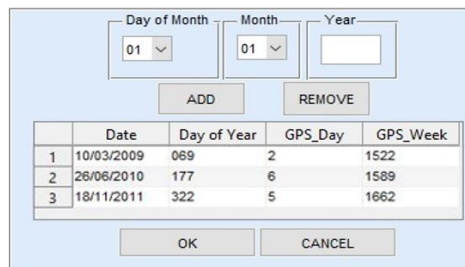

Figure 3. DDP Entry Data Screen

The COD files in Figure 4 (.ION (Ionosphere file), .TRO (Troposphere file), .EPH (ephemeris files), .CLK (clock corrections), .ERP (earth ratation parameters), .SUM (summary files), .SNX (SINEX file) extension files are obtained based on the GPS week and day values in the entry screen (URL 1) from the (www=GPS week) internet website. The downloaded .ION and .TRO files are saved to DATAPOOL/BSW52 folder, and the .EPH, .CLK, .ERP, .SUM and .SNX files are saved to the DATAPOOL/COD folder.
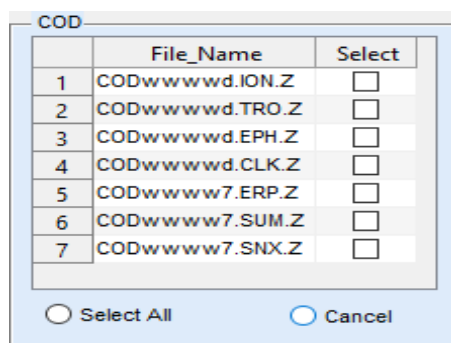

Figure 4. DDP COD Screen

The igs/igl (igs; from the GPS satellites, igl; from the GLONASS satellites) files in Figure 5 represent the sensitive ephemeris files (.sp3), Clock corrections (.clk), earth rotation parameters (.erp) and summary files (.sum) for GPS and GLONASS Satellites. The entry data are obtained from the (URL 2) Internet website for GPS satellites and from the (URL 3)

(www=GPS week, n=GPS day) for GLONASS satellites depending on the GPS week and day. The downloaded files are saved in the DATAPOOL/IGS.
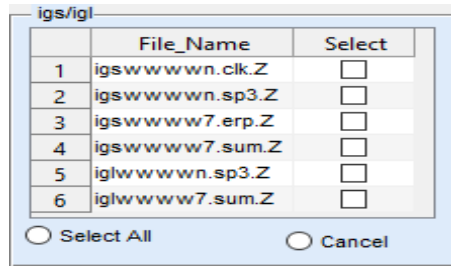

Figure 5. DDP Igs and Igl Screen

The GEN files given in Figure 6 are stable files and are obtained from (URL 4) Internet website. The important point in GEN files is the fact that they are updated from time to time, and for this reason, these files must be updated when needed. In addition, since the SATyyyy.CRX files belong to year, the data that belong to the year for which the campaign will be analyzed must be downloaded. The downloaded files are saved in C:\BERN52\GPS\GEN.
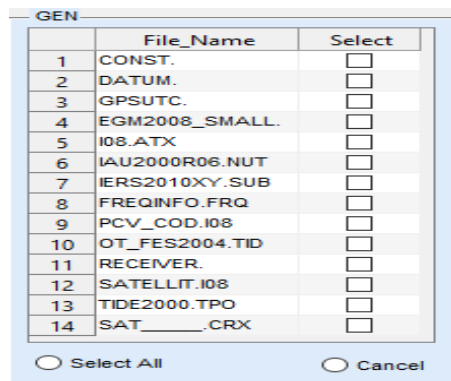

Figure 6. DDP GEN Screen

The DCB (Differential Code Bias) files, P1P2yymm.DCB (Ionosphere determination) and P1C1yymm.DCB (Hour prediction) given in Figure 7 are obtained from the (URL 1) Internet website depending on the year and month. The DCB downloaded files are saved in DATAPOOL/BSW52.
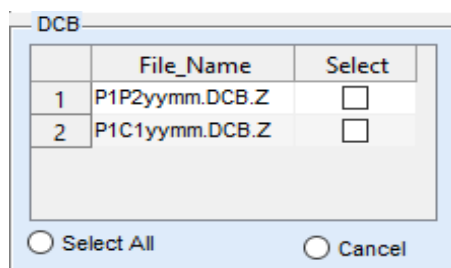

Figure 7. DDP DCB Screen

The STA files, and the Station's coordinates (.CRD), speed (.VEL), list (.FIX) files given in Figure 8 are obtained from the (URL 5) Internet website. The downloaded STA files are saved in DATAPOOL/REF52 folder.
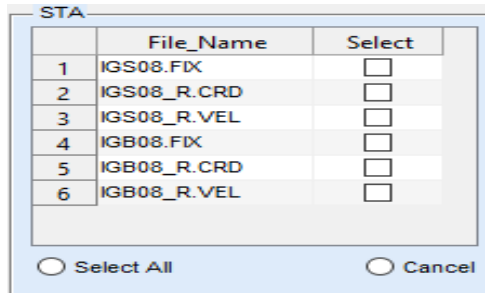
Figure 8. DDP STA Screen

In Figure 9, if there are IGS and EUREF Points, which will be used in evaluating the IGS and EUREF points field, the 4-character names of the relevant points must be written in the IGS Points and EUREF points sections. IGS Points are obtained from (URL 6) Internet website and EUREF Points are obtained from (URL 7) Internet website. The downloaded data on the relevant points are saved in DATAPOOL/RINEX folder.
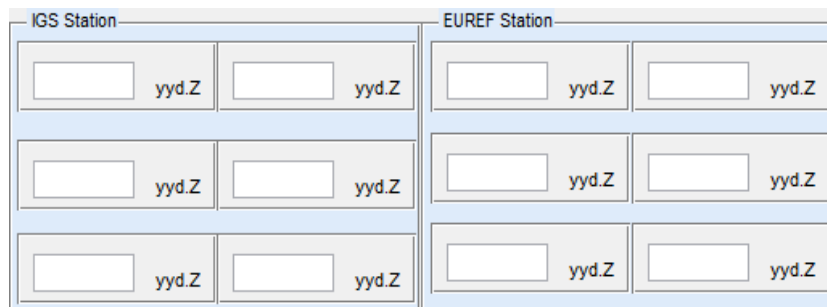

Figure 9. DDP IGS and EUREF Points Screen

After all the selections are made, the downloading process is started by clicking on the "OK" button. After the downloading process is completed, the information on where and in which folder the downloaded files are saved are given in "Downloaded" and "Not downloaded" (Figure 10) sections.
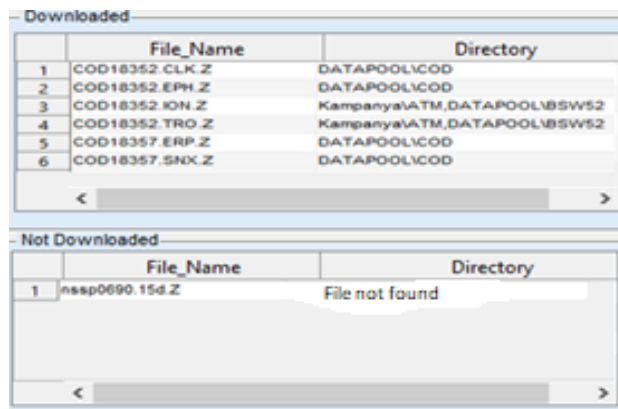

Figure 10. DDP Downloaded and Non-Downloaded Data Screen

2.3.   Evaluation of the Data

In order to perform data analysis in the Bernese v5.2 Software, first of all, the CAMPAIGN, which belongs to the day to be analyzed, must be created. For the analysis, after the definition of the CAMPAIGN is made for the relevant day, the DDP and the files that are required for the analysis of the data are saved in the relevant folders in the DATAPOOL index, which is created with the installation of the Software. Since after the analysis with the Bernese v5.2 GNSS Software, the Regional Ionosphere Model will be used, the analysis has been made by using the PPP_DEMO.PCF ready command from which this model was obtained. A 7-stage analysis is made when the Regional Ionosphere Model is obtained. These stages and the relevant processes are listed below (URL 2).

- Copying of the Required Files,
- Preparation of the Pole, Orbit and Clock Information,
- Synchronization and conversion of the Observation Files,
- Computation of Station PPP Analyses,
- Computation of NNR-NUVEL1-A Speeds (if desired),
- Special Analyses: Geocenter estimation, Pseudo-kinematic analysis, high-rate troposphere, Station-specific Ionosphere/DCB estimation, Regional Ionosphere model/DCB estimation
- Termination of BPE

Analysis occurs upon the running of PPP_DEMO.PCF command, and after the 7th Stage is completed, results are copied under the CAMPAIGN folder.

3. Application

In this study, a total of 20 stations are used to create a Regional Ionosphere model, and 8 of the stations are TUSAGA-Active Station, and the rest are IGS Stations. TUSAGA-Active Station Data were obtained from the (URL 11) websites, and the data about IGS Stations were obtained from (URL 12) websites. The Regional TEC values of the year 2014 for the selected region were found by making use of the Bernese v5.2 GNSS Software. For the purpose of comparing the TEC values, the GIM values produced by CODE, ESA and JPL and the IRI-2012 (International Reference Ionosphere) model that was produced by Committee on Space Research (COSPAR) and International Union of Radio Science (URSI). The TUSAGA-AKTİF (CORS-TR) and IGS (International GNSS Service) Stations used in the analyses are given in general in Figure 11. To compare the Regional TEC values obtained with the GNSS measurements with Bernese v5.2 Software, the GIM-TEC values released by CODE, ESA and JPL were downloaded from the (URL 9) website, and the TEC values obtained from IRI were computed by entering the longitude and latitude of the relevant day in an online manner on the (URL 10) website. The Regional TEC values obtained in the analysis of the stations used in the study and the minimum, maximum, average TEC values and the standard deviation obtained from the global TEC values are given in Table 1.

Table 1. Statistical Results Produced from the Regional and Global TEC Values for the Year 2014

Station Name	Ionosphere Models	Minimum TEC	Maximum TEC	Average TEC	Standard Deviation (TECU)
CANK	RIM	12.5	37.0	22.56	9.41
	CODE	13.4	36.3	23.12	8.76
	ESA	12.4	38.4	23.75	9.76
	JPL	13.9	38.7	24.40	9.44
	IRI	4.5	23.2	11.87	7.17
HYMN	RIM	12.8	38.3	23.38	9.80
	CODE	13.0	36.5	22.92	8.84
	ESA	12.4	38.5	23.57	9.70
	JPL	13.8	38.2	24.23	9.31
	IRI	4.7	24.1	12.46	7.43
INEB	RIM	12.3	36.2	22.05	9.23
	CODE	12.7	35.2	22.17	8.38
	ESA	12.3	36.1	22.51	9.06
	JPL	13.6	37.6	23.51	9.09
	IRI	4.4	22.7	11.61	7.02
SINP	RIM	12.0	36.4	21.86	9.33
	CODE	12,9	35.4	22.32	8.39
	ESA	12.2	36.3	22.62	9.13
	JPL	13.5	37.5	23.40	9.14
	IRI	4.4	22.7	11.60	7.05
TOKA	RIM	12.5	38.3	23.04	9.78
	CODE	13.2	36.5	22.98	8.79
	ESA	12.5	38.3	23.68	9.75
	JPL	14.0	38.9	24.43	9.47
	IRI	4.7	23.5	12.12	7.36
VEZI	RIM	12.2	37.2	22.37	9.51
	CODE	13.1	36.8	23.12	8.81
	ESA	12.6	38.5	23.80	9.83
	JPL	14.1	39.0	24.51	9.50
	IRI	4.5	23.1	11.86	7.17
YOZT	RIM	12.7	38.0	23.15	9.70
	CODE	13.3	36.6	23.21	8.82
	ESA	12.7	38.9	23.72	9.76
	JPL	13.8	39.1	24.47	9.45
	IRI	4.6	23.6	12.13	7.33
ZONG	RIM	12.4	36.7	22.38	9.36
	CODE	13.2	36.8	23.16	8.84
	ESA	12.5	38.8	23.67	9.74
	JPL	14.1	38.4	24.42	9.25
	IRI	4.5	23.5	11.88	7.12

The drawing of the TEC values was made with the **MATLAB** Program. As a result of the evaluations, the average TEC values that were produced for the days in 2014 with 2-hour

intervals were compared with the IRI and Global (JPL, ESA, CODE) Average TEC values (Figure 12-13). The horizontal axis in the graphic shows the universal time as hours, and the vertical axis shows the TEC values in TECU.
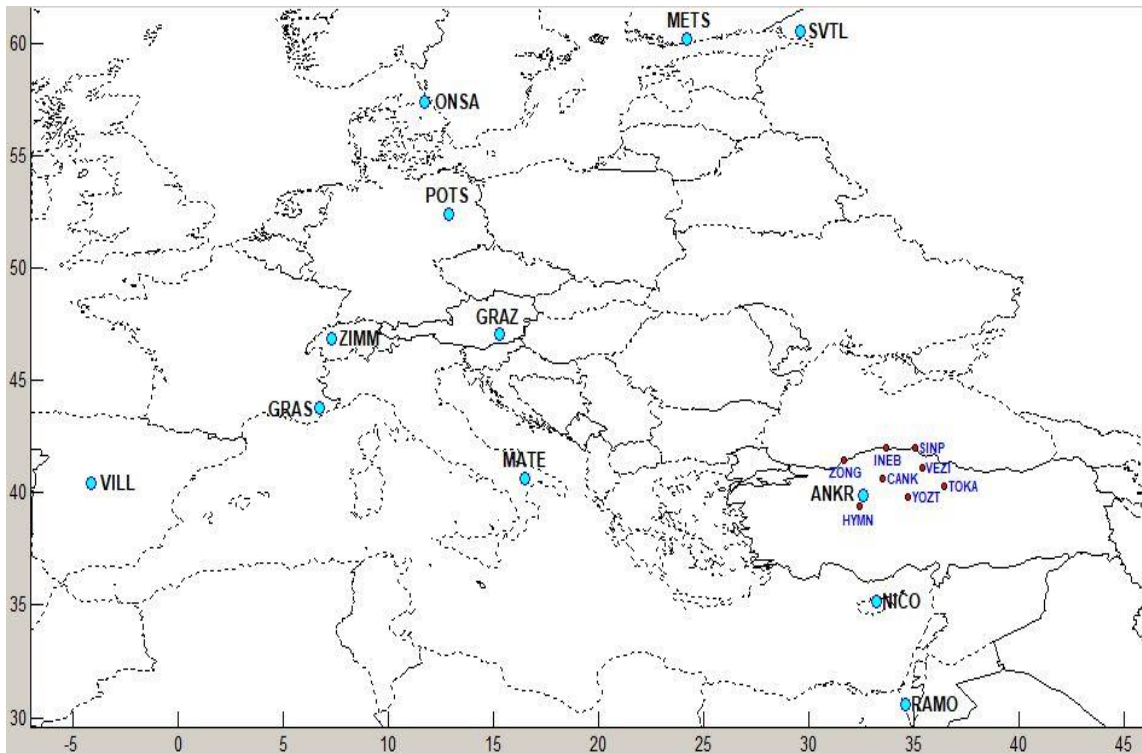

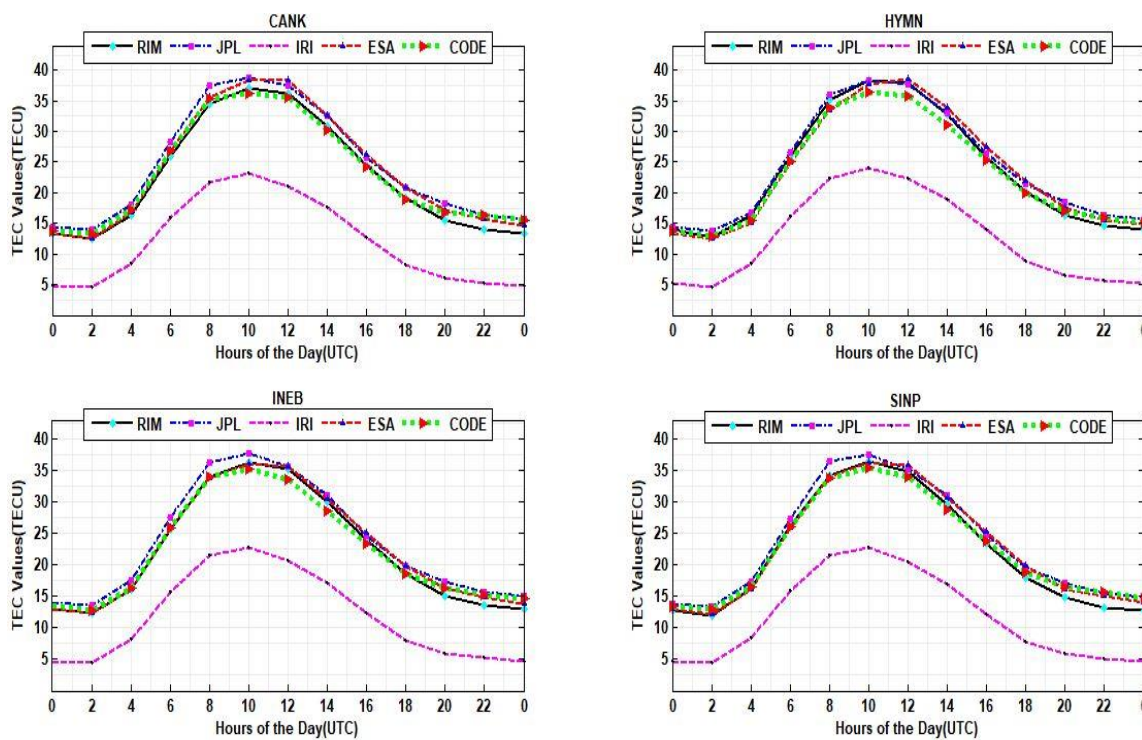**Figure 11.** Distribution of Stations

Figure 12. Comparison of Average TEC (RIM-Result) Values Obtained as a result of the Analyses of CANK, HYMN, INEB, SINP Points, and CODE, ESA, JPL, IRI Values
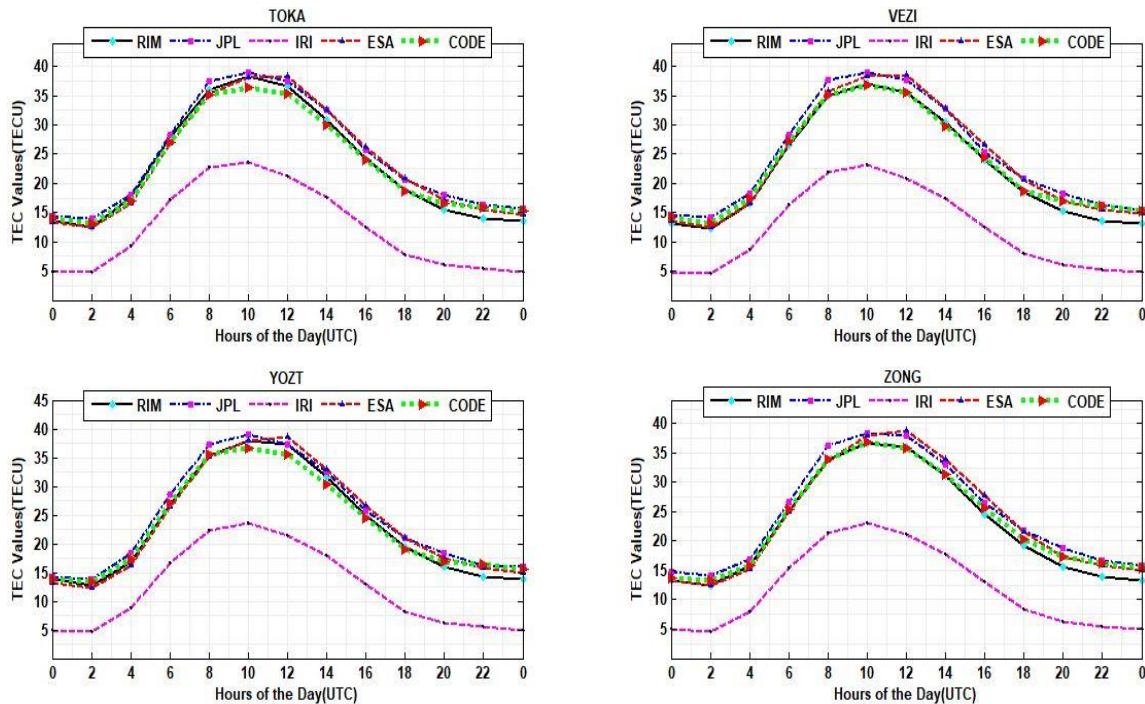
Figure 13. Comparison of Average TEC (RIM-Result) Values Obtained as a result of the Analyses of TOKA, VEZI, YOZT, ZONG Points, and CODE, ESA, JPL, IRI Values

4. Results

In this study, the purpose was to investigate the MATLAB-based Data Downloading Program (DDP), which enables that the files in Bernese format are downloaded from the Internet, and to compare the Regional TEC values obtained with the Bernese v5.2 GNSS Software by using the files downloaded with the DDP with the global models. When Figure 12 and Figure 13 are analyzed, it is observed that the Regional TEC (RIM) values and the TEC values obtained with the global (CODE, ESA, JPL) model and IRI are at the lowest level at 02.00 at night, and at the highest level at 10:00.

When Table 1 is analyzed, it is observed that the Regional TEC values (RIM) and the global TEC values (CODE, ESA, JPL) are in agreement, and the difference between them is maximum at 2.1 TECU level. The TEC values obtained from IRI-2012 are lower than the Regional TEC (RIM) values, and the difference between them reaches maximum 14.8 TECU level. According to the Regional TEC (RIM) values, it is observed that the highest Standard Deviation is 9.80 TECU, global (CODE, ESA, JPL), the highest Standard Deviation according to TEC values is 9.83 TECU; and the highest Standard Deviation is 7.43 TECU according to IRI-TEC values.

5. Conclusion

Ionosphere may be monitored with various ways like ionosonde, backscattering radar, and TOPEX/Poseidon satellite. Since these equipment is expensive and provide limited data on the Ionosphere, GNSS has become the most important method to investigate Ionospheric behavior.

In the present study, the files in Bernese format, which are required for the purpose of creating an Ionosphere Model, have been shown in one single window by creating an

interface with the help of MATLAB GUI. With this interface, the following items have become possible for users;

- The user can see that the day of the year, GPS day, and GPS values are written automatically according to the date entered;
- The user can observe that the data of the IGS and EUREF Station, which will be used in evaluations with the files in Bernese format according to the day of the year, GPS day, GPS week values are automatically downloaded from the relevant Internet addresses and copied to the DATAPOOL folder;
- The user is saved from negative factors like distractibility, decrease in interest, loss of time because there is visuality in the interface.

It was observed that there is a great deal of similarity between the Regional (RIM) TEC values and global (CODE, ESA, JPL) TEC values, which were obtained as a result of evaluations; and the TEC values obtained from IRI-2012 are lower when compared with these four values. It was also observed that, in general, the five TEC values increased until noon hours, and then, they decreased due to the merger of the ions that are free.

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