Space Weather of the Heliosphere: Processes and Forecasts
Proceedings IAU Symposium No. 335, 2017
C. Foullon & O.E. Malandraki, eds.

doi:10.1017/S1743921318000078

Variability of the Vertical Total Electron Content, from GPS data, during 2 to 8 November 2015, Using Oukaimeden and Rabat Stations in Morocco

Khaoula El bouyahyaoui[1], Aziza Bounhir[1], Zouhair Benkhaldoun[1], Rolland FLEURY[2], Christine Amory-Mazaudier[3] and Mohamed Kaab[1]

[1]Oukaimeden Observatory, LPHEA, FSSM, Cadi Ayyad University
[2]IMT Atlantique Bretagne-Pays de la Loire, campus de Brest, technopole Brest-Iroise, CS83818, 29238 Brest cedex 3.
[3]University Paris Sorbone UPMC, LPP Polytechnique, UPMC Jussieu 75005, France., Francen

Abstract. In this work we present a method for detecting the activity of the ionosphere (TEC) and we illustrate the signature of the solar activity on the vertical total electron content VTEC, during 02 to 08 November 2015, using GPS measurements obtained from two stations in Morocco, the first one in Marrakech at Observatory of Oukaimeden OUCA (31°12′23.3" N 7°51′58.8" W), the second in Rabat, Rabt ($33.9981°N; 353.1457°E, geographic$).

Keywords. Ionosphere, TEC, GPS

1. Introduction

Space weather today is a new field in science and has very interesting effects on humans, environment and technology in general. Scientists are now studying space weather with a wide range of tools to try to learn more about the physical and chemical processes taking place in the upper atmosphere and beyond. One of these tools is Global Positioning System (GPS). The ionosphere has practical importance in GPS applications because it influences the transionospheric radio wave propagation. The parameter of ionosphere that produces most of the effects on radio signals is the total electron content (TEC).

2. Total Electron Content in Ionosphere

The TEC is defined as the total number of electrons integrated along the path from the receiver to each GPS. The TEC as an indicator of ionospheric variability. It is derived by the modified GPS signal flowing through the ionosphere. TEC is measured in units of 10^{16} electrons per square meter area, where 10^{16} electrons$/m^2 = 1$ TEC unit (TECU) (Ouattara *et al.* 2012).

The TEC has been determined by modeling the ionosphere as a single electric layer. We show that the ionospheric TEC can be expressed as a function of the difference between two pseudo ranges or two carrier phases carried out by using the two typical GPS frequencies.

In this work, the TEC is observed at the F layer because this region has the highest variability of free electrons, causing the greatest effect on GPS received signal compared to other layers. More than two-thirds of electron concentration are located at F2 layer. This method is conducted by going through several processes (Zoundi *et al.* 2012). Figure 1 shows the flow chart of work progress to achieve the objective of the project.

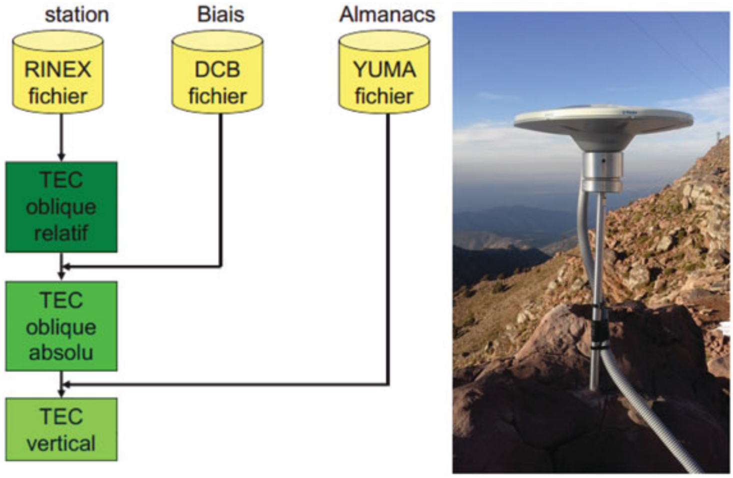

Figure 1. Left: Flowchart of TEC processing by Fleury model. Right: GPS at OUKAIMEDEN

The fundamental GPS frequency is $f_0 = 10.23MHz$ from which f_1 and f_2 are derived ($f_1 = 154f_0$ and $f_2 = 120f_0$) , defined the group delay as:

$$P_1 - P_2 = 40.3\,\text{TEC}\left(\frac{1}{f_1^2} - \frac{1}{f_2^2}\right) \tag{2.1}$$

P_1 and P_2 are the pseudo ranges for f_1 and f_2 respectively. By rewriting the equation of group delay, we obtain:

$$TEC = \frac{(P_1 - P_2)}{40.3}\frac{f_1^2 f_2^2}{f_2^2 - f_1^2} \tag{2.2}$$

The TEC between the satellite and the user depends on the satellite elevation angle, this measurement is called Slant TEC (STEC). The TEC varies temporally and spatially, and depends on the solar activity, user location, and the satellite elevation angle. This measurement is named vertical TEC (VTEC). To convert STEC to VTEC, we used the following equation:

$$VTEC = (STEC - B_s - B_u)\sqrt{1 - \left(\frac{R_e\cos(\epsilon)}{R_e + h_s}\right)^2} \tag{2.3}$$

where B_s and B_u are the instrumental biases of satellites and receivers respectively, $R_e = 6371km$ is the mean radius of the Earth, ϵ is the elevation angle of the satellite (Titheridge 1972).

The process of extracting data from RINEX (Receiver Independent Exchange) file was done by using Matlab programming language whereby the RINEX file was obtained from the GPS receiver as shown in figure 1. The program will analyze and extract the information needed for calculating the TEC from the observation and navigation RINEX file. The result will show the graph of vertical TEC (VTEC) versus time. Data of VTEC were used since its value is independent on the location of satellite receiver compared to STEC (Shimeis *et al.* 2002).

3. Results

Figure 2 shows the hourly variation of VTEC for seven selected days of November 2015 based on the data availability.

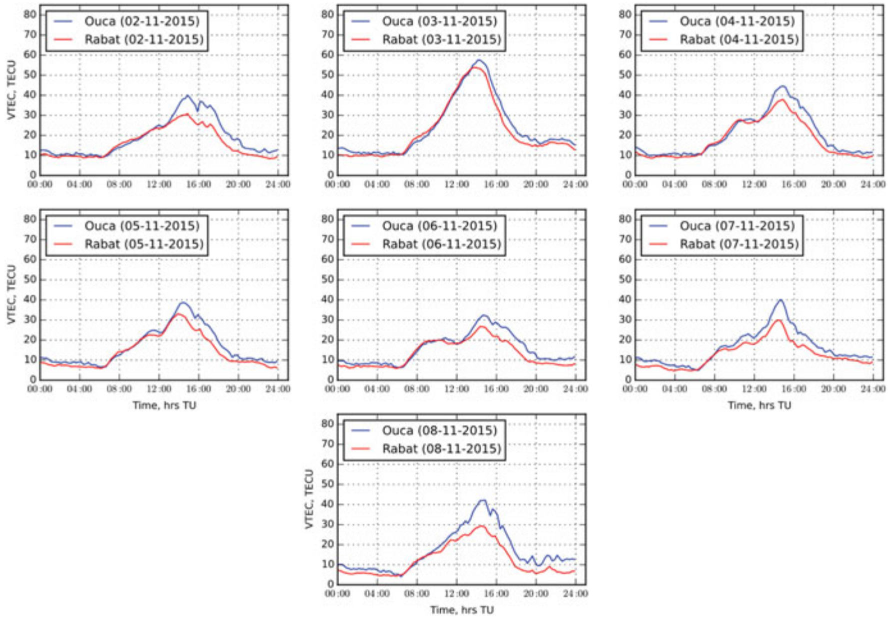

Figure 2. Local time variation of Rinex TEC for: 02-08 November 2015 from GPS at OUKAIMEDEN and Rabt.

According to ACE satellite, a co-rotating interaction region followed by higher speed stream from an equatorial coronal hole arrived at earth on 3 November 2015. The solar wind speed jumped from around 320 km/s to about 700 km/s. The high speed stream caused on 3 November a ionospheric event, as a result, the TEC increases by about 20 TECU between 12UT and 16 UT.

We can notice from Figure 2 that the TEC over Oukaimeden and the TEC over Rabat correlate, but with an enhancement of the TEC over Oukaimeden in afternoon hours. This result is expected as Oukaimeden is closer to the maximum equatorial ionization anomaly crest than Rabat.

4. Conclusion

The TEC is measured by its effect on the travel time of the signal between the satellite and the receiver. We have given the expression of the TEC and presented clearly the algorithm for calculating it. For the station of Oukaimeden, we showed for the first time the variability of the VTEC in the region. The present work illustrates the variability of the TEC in two stations located in Morroco from 02 to 08 November 2015 by using the Fleury model (Ouattara *et al.* 2012).

References

Ouattara, F., Zoundi, C. & Fleury, R. 2012, *Indian Journal of Radio and Space Physics*, 41 (6), pp 617–623

Zoundi, C. & Ouattara, F. 2012, Sciences et Médecine. Rev.CAMES-Série A, 13(2):139–143

Shimeis, A., Amory-Mazaudier, C., Fleury, R., Mahrous, A. M. & Hassan, A. F. 2014, *Advances in Space Research*, 54, 2159–2171

Titheridge, J. E. 1972, *Journal of Geophysical Research* 77 (10), pp 1978–1981

https://doi.org/10.1017/S1743921318000078 Published online by Cambridge University Press