An investigation of Solar Radio Bursts impact on ionospheric Total Electron Content

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ABSTRACT

Solar transients events such as Coronal Mass Ejections (CMEs) and solar flares represents the cause of various aspects of space weather and its impact on modern man made technological system. Such solar transients are often associated with solar radio bursts (SRBs), particularly of type II and III that at ground level can be detected by the CALLISTO (Compact Astronomical Low-frequency Low-cost Instrument for Spectroscopy and Transportable Observatories) solar spectrometer. SRBs are radio waves that are generated during solar transients events, mostly solar flares. Radio emissions result from a series of physical processes in the solar atmosphere. In general, SRBs are thought to be produced by the plasma emission mechanism [2]. If SRBs propagate towards the earth, they can affect Earth's space environment and represent an aspect of space weather. Previous research studies [3, 7, 1] have investigated the impact of SRBs on GNSS signals. Early research studies [e.g. 4] and most recent ones [e.g. 8, 6] demonstrated the relationship between SRBs and changes in TEC.

The aim of this study is to investigate SRBs impact on global positioning system (GPS) derived total electron content (TEC). The present study is only limited to establishing the correlation between solar bursts events and TEC behavior during the bursts time. SRBs data used are dynamic spectra covering the 2014-2015 period and detected by the CALLISTO instrument installed at the University of Rwanda in Kigali (1.94° S, 30.05° E). To investigate ionospheric impact, we use TEC data from GNSS stations that are located at almost the same universal time zone. TEC data are processed from RINEX files using a software program developed by [5]. TEC data was considered with elevation angle greater than 20 degrees in order to minimize the multi-path errors. On the other hand, the STD format files contained averaged VTEC in 1 min intervals. The VTEC values were not farther averaged in larger interval time since SRBs under investigation are normally short duration solar events.

GNSS data used in this investigation are in four categories: (1) data for SRB day, (2) data for ten most quiet days in a month, (3) data for the day before burst and (4) data for the day after burst. In this study, we considered the day before and after burst day for taking into account other solar events that may have occurred in this period but also to check the TEC behavior on the days closest to the burst day. To identify quiet days from disturbed ones, we used data from international quiet days and international disturbed days Australian website (i.e http://www.ga.gov.au/oracle/geomag/iqd_form.jsp). Since TEC disturbances can occur following geomagnetic storms events, we checked on geomagnetic equatorial Dst index website (i.e http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html) to ensure that there was no storm event on days closer to the burst day. For these days, a day of Dst (≥ -50 nT) was considered as a no storm day. Table 1 shows an example of investigated SRBs events.

Burst day	Time of burst (UT)	Frequency (MHZ)	Type and quality	X flare class	Time of flare	Dst_min (nT)
14 Jan 2015	10:37-10:41	025-180	III/2	C5.3	09:17-09:52	-22
27 Dec 2015	07:33-07:36 08:09-08:09 12:00-12:02	025-180 035-135 025-180	III/2	B5.6 B5.6 B9.7	00:10-00:15 00:10-00:15 11:58-12:04	-33

Table 1: A sample of investigated SRBs.

Preliminary observations resulting from this study indicate a slight enhancement in TEC during the burst event days as shown by the right hand panel of figure 1 and 2. From right hand panel of figure 1, one can easily see that the peak in TEC corresponds to the time of occurrence of SRB and the difference between TEC of burst day and averaged TEC of ten quietest days in a month is approximately 15 TECU. From right hand panel of figure 2, it is clear that there is a remarkable increment in TEC due the occurrence of SRBs at 07:33-07:36 UT, 08:09-08:09 UT and 12:00-12:02 UT. The maximum difference between TEC of burst day and averaged TEC of ten quietest days in a month is about 5 TECU. The observed TEC enhancement on the burst day can be associated to increased UV and X-rays radiations and particle acceleration that are associated with SRBs events [8]. It is important to note that this research work is still going on. Observed changes in TEC during the burst time will be discussed further by taking into consideration of other spatio-temporal variability. This work can be a contribution to more understanding of the geo-space impact of solar transients phenomena for modeling and prediction.

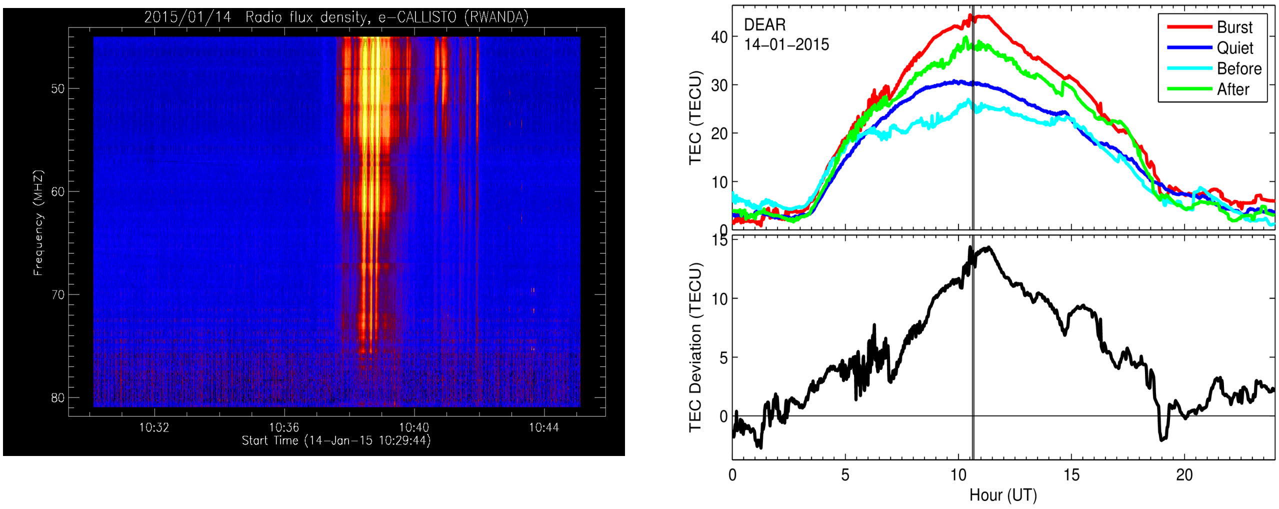

Figure 1: The left hand panel shows the dynamic spectra (i.e plot of intensities: y-axis is the frequency in MHZ and x-axis is the time in UTC) of type III SRB detected by a ground based CALLISTO-RWANDA, January 14, 2015. The right panel shows the ionospheric TEC enhancements: red indicates TEC enhancement during the burst day, blue indicates averaged TEC enhancement during ten quietest days in a month, cyan indicates TEC enhancement during the day before burst day and then green indicates TEC enhancement during the day after burst day; black shows TEC difference of burst day TEC from quiet days averaged TEC; two coincided vertical lines represent time interval of SRB and DEAR is an IGS station with coordinate (30.66 degrees South and 23.99 degrees East).

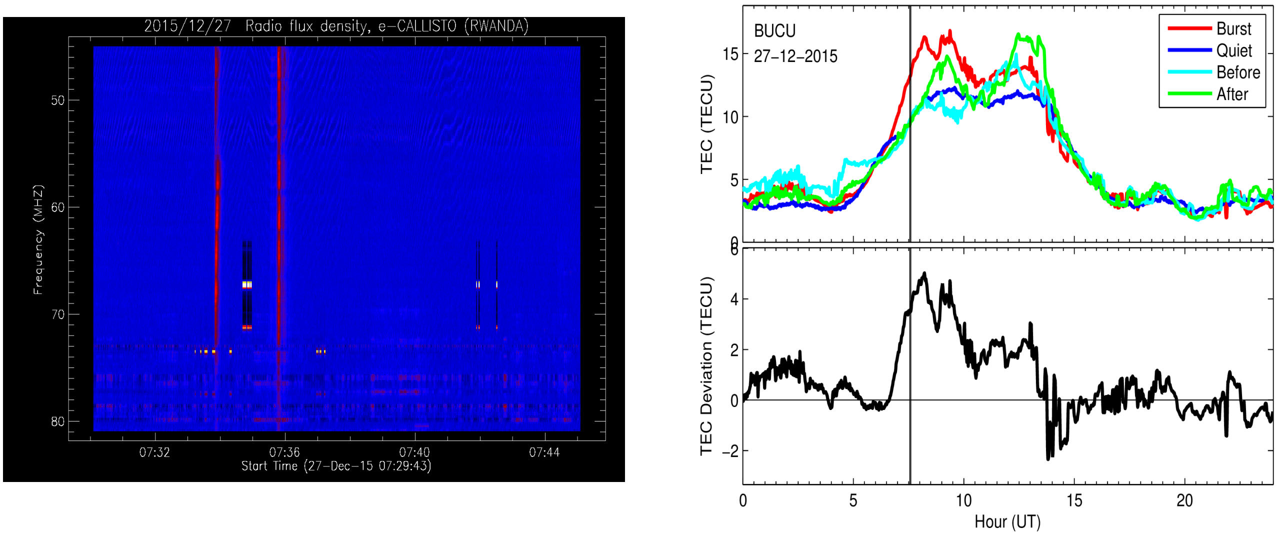

Figure 2: Similar caption like figure 1 except that left hand panel shows the dynamic spectra of December 27, 2015 ; and BUCU in right hand panel is an IGS station with coordinate (44.46 degrees North and 26.12 degrees East).

Key words: GPS derived TEC, solar radio bursts, CALLISTO, space weather.

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