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An approach to study TEC gradients variability and their role in driving scintillations

Claudio Cesaroni*

Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, Rome, Italy.
(E-mail: Claudio.cesaroni@ingv.it)

ABSTRACT

This presentation aims at contributing to the understanding of the relationship between the ionospheric plasma irregularities and the scintillation occurrence at low latitudes. To accomplish this task, data from combined GNSS networks in Brazil are properly analysed to highlight the relationship between intensity and variability of the TEC gradients and the occurrence of ionospheric scintillation. The importance of the information provided by the TEC gradients variability and the role of the meridional TEC gradients in driving scintillation are shown and discussed.

Key words: Equatorial Ionosphere, GNSS, GBSC, calibrated TEC, TEC gradients, Scintillation.

Introduction

At low latitudes, the interplay between **E**x**B** drift, gravity and pressure gradients, leads to an enhancement of ionization in the regions close to ±15° magnetic latitude, commonly referred as the northern and southern crest of the Equatorial Ionization Anomaly (EIA), respectively. The Rayleigh-Taylor instability, caused by the formation of the crests, allows the formation of Ionospheric Plasma Bubbles (IPB), when some forcing from below (e.g. gravity waves) is present. The small-scale irregularities embedded in the IPB's are the main sources for the equatorial scintillations that occur in particular during the post-sunset hours [1]. Traditionally, the relation between TEC (Total Electron Content) variation and scintillation is investigated by means of the ROT (Rate of TEC) and, in particular, of the ROTI (ROT Index) [2]. According to its definition, ROTI mixes both spatial and temporal gradients. The aim of this work is to focus only on the role of spatial gradients in driving scintillation, disentangling also the contribution to the TEC variations due to zonal and meridional gradients [3].

Data analysis

GNSS measurements from the São Paulo State University (UNESP) Real Time Kinematic Network (URTKN) during the whole 2012 are used to derive regional maps of TEC. The corresponding scintillation environment is investigated by using a network of multi-constellation receivers (Septentrio PolaRxS) covering the ionosphere over São Paulo state, deployed and maintained in the framework of the CIGALA (http://cigala.galileoic.org/) and CALIBRA (http://www.calibra-ionosphere.net/) projects. The first step of the analysis (fully detailed in [3]) is the calculation of calibrated TEC from GNSS code and phase carrier delays necessary to estimate the different offsets introduced by the satellites and receivers clock errors, multipath, phase ambiguity and cycle slips [4]. Regular calibrated TEC grids are then obtained through the natural neighbour interpolation technique. Such grids are then used to derive the spatial gradients of TEC and related regional maps along geographical North-South and East-West directions, respectively defined as follows

$$\Delta TEC_{N-S}\left(GP_{i,j}\right) = \frac{TEC\left(GP_{i+1,j}\right) - TEC(GP_{i,j})}{d_i} \tag{1}$$

$$\Delta TEC_{E-W}\left(GP_{i,j}\right) = \frac{TEC\left(GP_{i,j+1}\right) - TEC(GP_{i,j})}{d_j} \tag{2}$$

where $\Delta TEC_{N-S;E-W}\left(GP_{i,j}\right)$ is TEC gradient along the North-South (East-West) direction calculated for the point of the grid (GP) with coordinates (*i,j*), $TEC\left(GP_{i+1,j}\right)$ is the TEC value of the first northerly (easterly) point of the grid with respect to (*i,j*), $TEC(GP_{i,j})$ is the TEC value of the considered grid point (*i,j*) and d_i is the distance between (i+1,j) and (*i,j*) points.

Finally the GBSC [5] is applied to the amplitude scintillation index (S4) and to the calibrated TEC gradients to highlight their seasonal variability and their interconnection.

Results and conclusion

As an example, Figure 1 shows climatological maps of different ionospheric parameters from GBSC as obtained for spring 2012. By disentangling the contribution to the TEC variations due to zonal and meridional gradients, it is possible to obtain insight into the relation between the scintillation occurrence and the morphology of the TEC variability. The N-S gradients are significantly larger than their E-W counterparts are, regardless of the season are. This reflects the fact that the ionospheric irregularities tend to elongate along the magnetic meridian, therefore giving most of their contribution along the geographic N-S direction, as opposed to very little contribution on the E-W direction. The most intriguing feature of this investigation stands in the observed relation among standard deviations of TEC gradients ($\sigma(\Delta TEC_{N-S})$, $\sigma(\Delta TEC_{E-W})$) and the scintillation occurrence. In particular, the correspondence with the S4 occurrence indicates the variability of the N-S gradients as the principal driver of the amplitude scintillation. In detail: despite the fact that $<\Delta TEC_{N-S}>$ reaches larger values in the fall (here not shown) than in the spring (Figure 1), the level of scintillation is almost absent (below 6%) in the fall, while in the spring it exacerbates. Thus, at least from a climatological standpoint, the presence of meaningful gradients alone is not sufficient to trigger the occurrence of scintillation, instead, for this to happen, it must be associated with large variability of the gradients themselves. This is very noticeable and can drive future development of climatological models of scintillation for the low latitude ionosphere.

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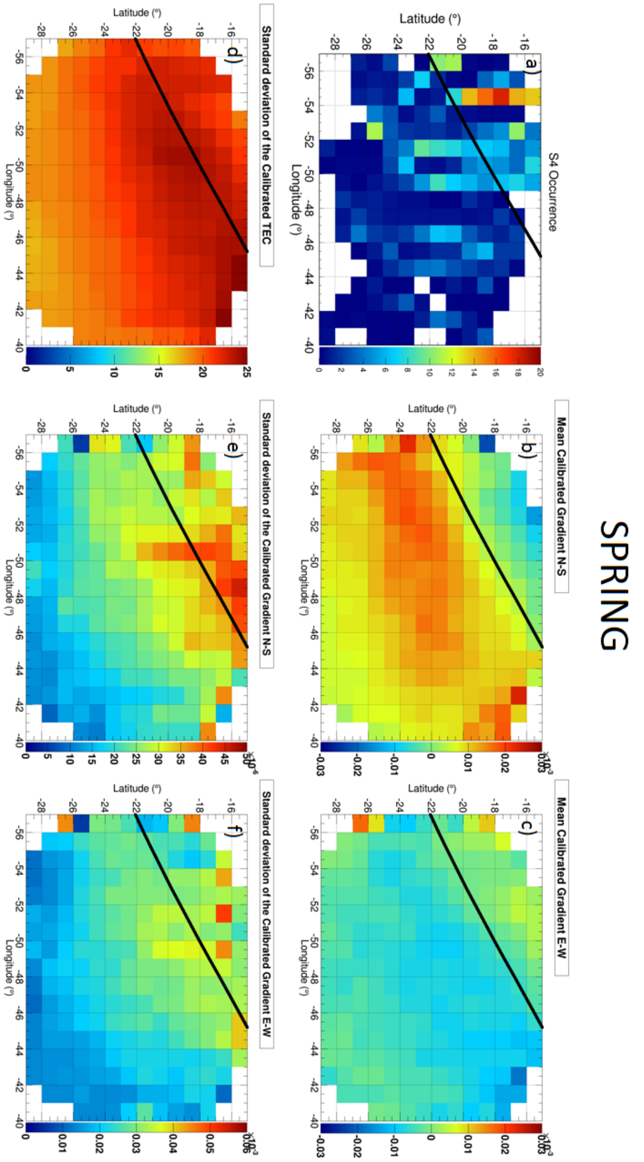

Figure 1. Climatological maps of different ionospheric parameters from GBSC for spring days. S4 occurrence (panel a), mean calibrated TEC gradients along N-S direction (in TECu·km^{-1}, panel b) and its standard deviation (in TECu·km^{-1}, panel e), mean calibrated TEC gradients along E-W direction (in TECu·km^{-1}, panel c) and its standard deviation (in TECu·km^{-1}, panel f), standard deviation of the calibrated TEC (panel d, in TECu). Black line represent 15th southern magnetic parallel.