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COLAGE XI

Influence of the Temporal Resolution of averaged TEC values on the accuracy of the Disturbance Ionosphere Index

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Abstract

In the present work, we show the preliminary results of effects in the accuracy of the Disturbance Ionosphere Index (DIX) when using different temporal resolutions of the Total Electron Content (TEC) averaged during magnetically quiet-time conditions (meaning quiet ionosphere) as a baseline for deriving it. DIX is an index primarily dedicated to express the response of the ionosphere to magnetic disturbances. Thus, we assume that different temporal resolutions of averaged TEC will express different degrees of the background quiet iPonosphere variation that are considered in the DIX calculation. Therefore, we calculated the averaged TEC values from the quiet ionosphere for several different selected groups of quiet time (e.g. hours, days, weeks, months, and seasons). The results are presented and discussed in terms of the statistical analysis, focusing on the determination of the most mathematically appropriate method with physical meaning to represent the variation of ionospheric electronic density under quiet conditions.

Introduction

Ionospheric disturbances have a strong influence on the performance of radio-based space systems (e.g., GPS, Galileo, BeiDou, and Glonass). These effects may include errors caused by rapid phase and amplitude fluctuations in satellite signals, as well as interruptions in the satellite-receiver connection (Klobuchar, 2006). An interesting example of ionospheric disturbance is the plasma bubble occurrence, which corresponds to depletions in the ionospheric density. These disturbances can be observed in the TEC curve behavior (Abdu, 2003). Moreover, external disturbances (e. g. magnetic storms) also affect the TEC variation. Jakowski et al. (2006) proposed a Disturbance Ionosphere Index (DIX) based on TEC data. That index was designed to quantify the perturbation degree of the ionosphere, and, at first, express the ionospheric response of magnetic disturbances. This work intends to contribute to the improvement of DIX, analyzing its accuracy from the use of different approaches to represent the quiet ionosphere.

Methodology

The methodology proposed in this study is a modified version of the one presented in Jakowski et al. (2006). The DIX is defined from the deviation of TEC from a non-perturbed reference baseline such as monthly averages (in the original study). Thus, the index is defined by the following formula:

$$DIX = \sqrt{\left(\frac{TEC_i - \langle TEC_i \rangle}{\langle TEC_i \rangle}\right)^2}$$

In order to attenuate the plasma depletion effects, a quiet TEC daily profile is represented by the day with lowest Kp value, and without significant plasma depletions occurrences. Besides monthly averages, three other methods were used to calculate the quiet-ionosphere baseline. The first method consisted of a centered moving average of 0.5, 1 and 3 hours for the studied period. The method 1 can be given by (Chatfield, 1996):

$$\langle TEC_i \rangle = \frac{1}{2q+1}\sum_{r=-q}^{+q} TEC_{i+r} \qquad q = \begin{cases} ((N-1)/2), & if\ N\ is\ odd \\ (N/2)-1\,, & if\ N\ is\ even \end{cases} \qquad (1)$$

The second method consisted of an equation similar to (1), but this time using weights for the moving averages. For this method, a parabolic weight was used, with the weight area normalized to 1. For an averaged TEC point, $\langle TEC_i \rangle$, the weight which corresponds to the jth $(i + r)$ point is given by:

$$w_j = 1 - \left[\frac{(TEC_{i+r} - TEC_i)}{(N+1)/2}\right]^2 \qquad (2)$$

Lastly, the third method consisted of using the TEC data from the International Reference Ionosphere (IRI) model, as a attempt to represent quiet-ionosphere values, using the following relation:

$$\langle TEC_i \rangle = TEC_{IRI} \qquad (3)$$

Plasma Depletions Filtering

In order to filter plasma depletions effects, the entire period was represented by a N-repetition time series of the quietest day (Qd) of the period. However, if a Spread-F event were observed in the Qd1 (figure 1), the next Qd without Spread-F was used in the repetition.

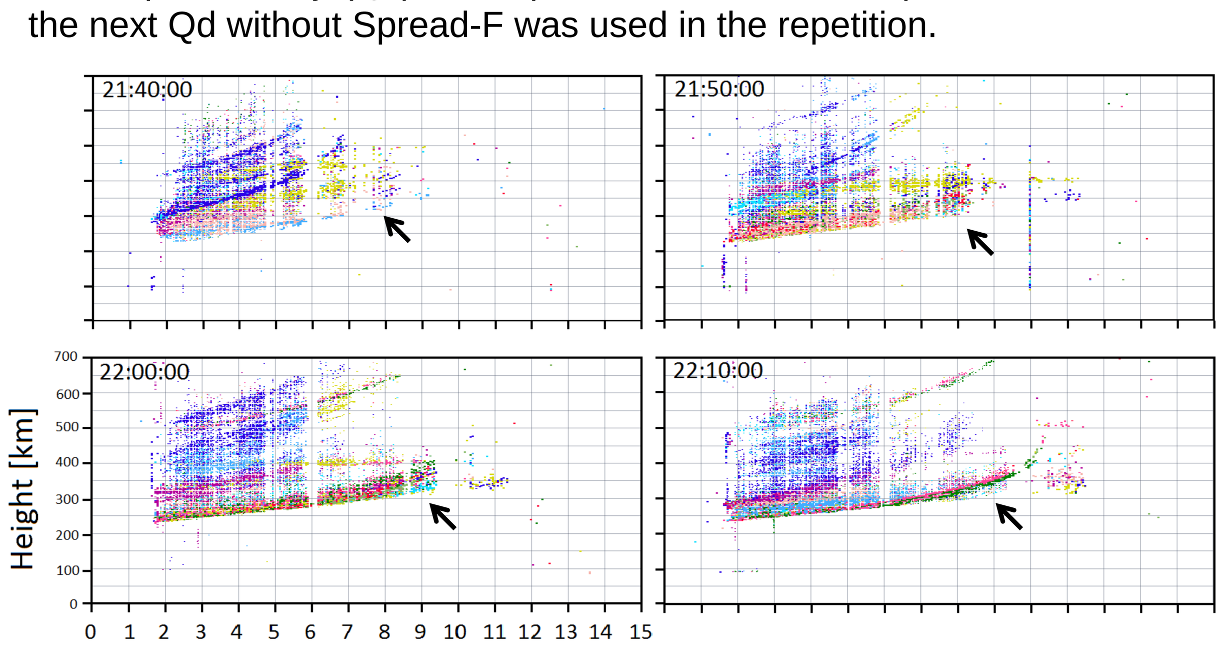
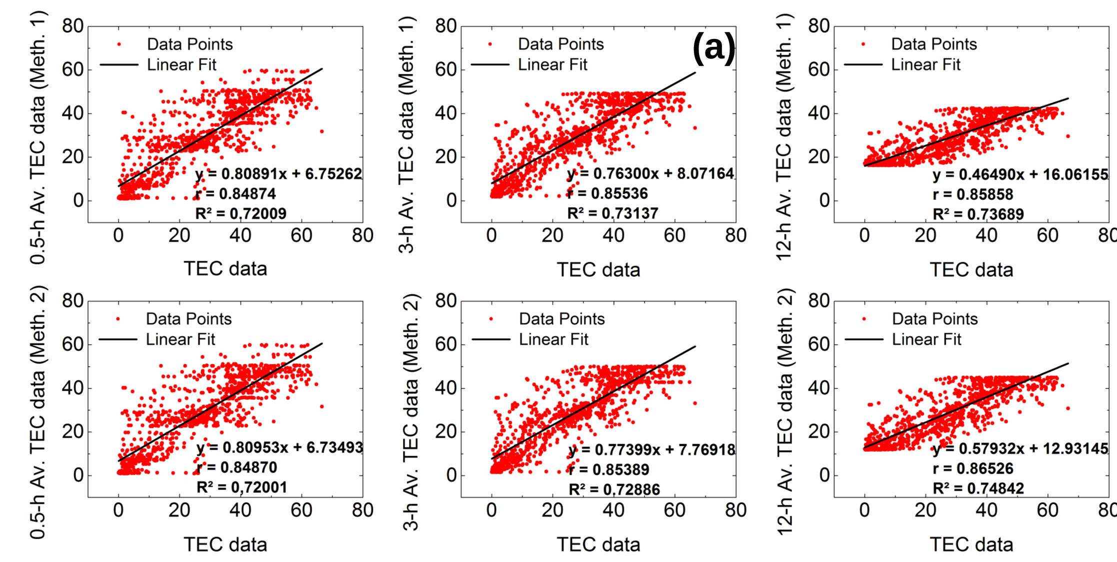


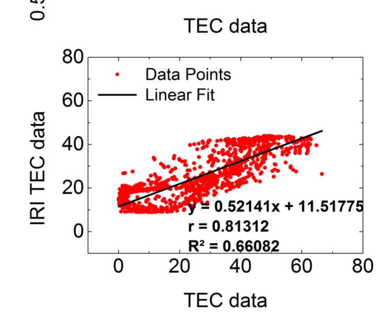
Fig. 1 – Ionogram showing the time evolution of Spread-F during the quietest day of the period. The black arrows indicate the Spread-F occurrences.

Cachoeira Paulista (22.4ºS, 44.5ºW), 24 Nov. 2015

Baseline determination

Considering only the Pearson coefficient (r), R-square value, and the linear fits coefficients, the most mathematically appropriate method to represent the DIX baseline is the centered moving average with a temporal resolution of 3-hour. Physically, it is also appropriated once we are looking for changes in the TEC values corresponding to the changes in the magnetic conditions of the Earth's magnetic field, which is usually available through disturbances indices like the Kp index.



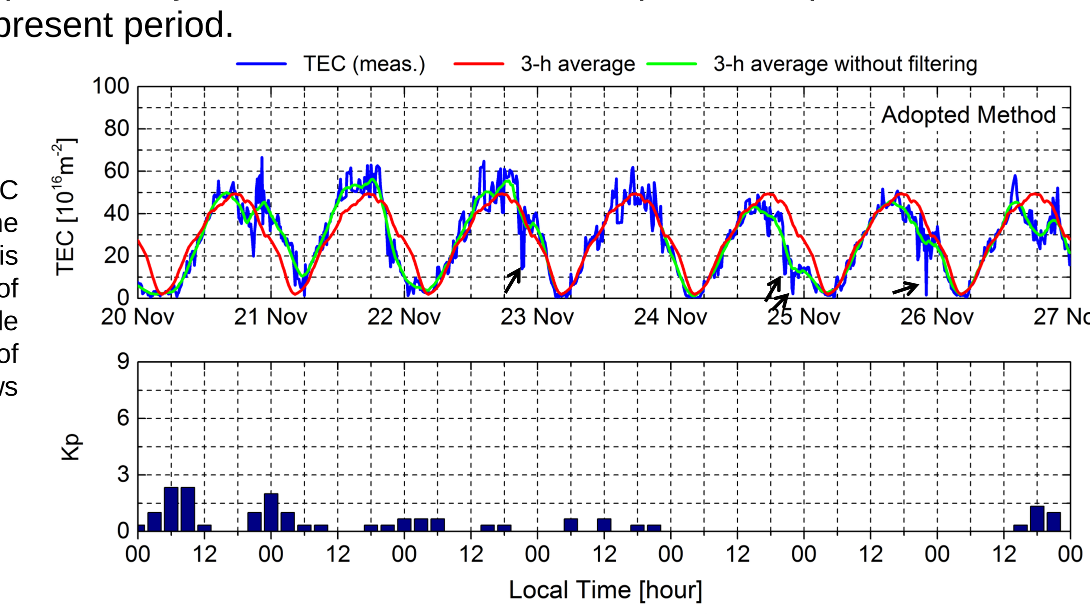


Standard Error (for each method)							
	0.5-h (M1)	0.5-h (M2)	3-h (M1)	3-h (M2)	12-h (M1)	12-h (M2)	IRI
Intercept	0.51734	0.51783	0.47435	0.48425	0.28496	0.34455	0.38315
Slope	0.01589	0.01591	0.01457	0.01487	0.00875	0.01058	0.01177

Fig. 2 – Scatter plots and statistical parameters of the proposed methods. Based on the observations, the chosen baseline was the one calculated from the method 1 using a temporal resolution of 3-hour (a).

The chosen baseline represents the quiet-ionosphere curve for a given period. Therefore, after selecting the mathematical tool over a three-hour period, we further analyzed the 7 quietest days of November 2015 (20 to 27) and selected the quietest day with no/few occurrence of plasma depletion. It resulted to be Nov. 23 as the baseline for the present period.

Fig. 3 – DIX baseline and measured TEC comparison. The blue profile represents the day-to-day TEC variation, while the red line is indicating the 3-h centered moving average of Nov. 23 as a baseline. The green profile represents the 3-h centered moving average of the respective analyzed day. The black arrows indicate some plasma depletions occurrences.



DIX calculation for a geomagnetically quiet period

Afterwards, the DIX was calculated for the period of November 20-27, 2015 (geomagnetically quiet period), using TEC data from a station on São José dos Campos, Brazil (23.2ºS, 45.8ºW). Plasma depletions can be observed along the DIX curve, and a strong ionospheric disturbance is detected at Nov. 21.

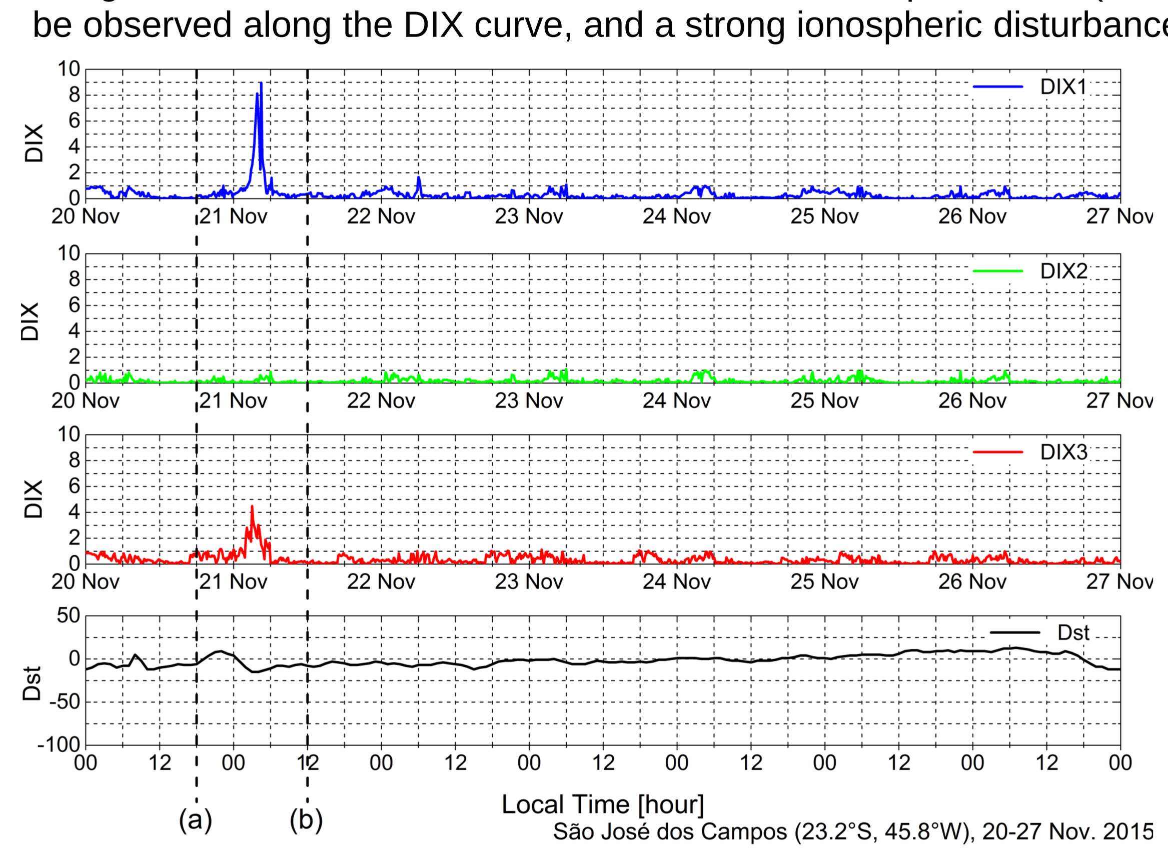


Fig. 4 - DIX 1 represents the index calculated using the method 1, with plasma depletion filtering. DIX 2 represents the DIX calculated using the method 1, without plasma depletion filtering. DIX 3 represents the DIX calculated using the baseline proposed by Jakowski et al. (2006). The (a) and (b) markers represent the start-point and end-point of a strong ionospheric disturbance.

Summary

- We have selected the most appropriate method to stablish the quiet-day profile, which is by using a centered moving average of 3-hours, filtering the plasma depletions.
- The proposed methodology has proved to be sensitive to small disturbances in the ionosphere, which is in agreement with the methodology proposed at Jakowski et al. (2006).
- A tentative explanation for the observed disturbance in the DIX at Nov 21, is tough in terms of the rising of the whole ionosphere. The complete explanation will require the investigations on the background thermospheric neutral density as well as solar wind interaction with the magnetosphere, which were not performed so far.

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Sponsors

Acknowledgments