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Estimates of ionosphere state over Mexico with TEC data.

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Abstract

The ionosphere behaviour over Mexico was studied. We analysed variations of Total Electron Content (TEC) and critical frequency of F2-layer of the ionosphere (foF2). TEC values were extracted from data of local GNSS receivers and if missed then from global ionospheric maps. foF2 values were reconstructed using TEC measured over Mexico and equivalent slab thickness of the ionosphere measured in the adjacent to Mexico regions having ionosondes. Diurnal and seasonal patterns of TEC and foF2 behaviour over Mexico were revealed. The peculiarity of TEC behaviour during disturbances were studied. The presence of strong positive enhancements is a characteristic feature for Mexico that is confirmed by measurements of electron concentration at satellites CHAMP and DSMP.

1. Introduction

The study of the Earth's ionosphere's state is one of the key issues within Space Weather monitoring and research, because Space Weather event manifestations in the ionosphere can influence unfavorably various types of modern technology. There are different ionospheric parameters characterizing the ionosphere state. Vertical and oblique ionospheric sounding by ionosondes and Total Electron Content data (the quantity of electrons in a column of unit cross section) are among the principal sources of the information about the ionosphere. Total Electron Content (TEC) is derived from data of GNSS receivers. For the areas with large distances between receivers and ionosondes the international global ionospheric maps can be used additionally. From 2015 the continuous monitoring of TEC variations over the territory of Mexico is performed by the Mexican Space Weather Service (SCiESMEX) [1]. At the moment there is no available ionospheric sounding data in Mexico. To monitor space weather conditions, SCiESMEX uses global data from international sources and local observations from a network of ground-based instruments associated with the Space Weather Laboratory (LANCE). The data from TLALOCNet and SSN networks of GNSS receivers in Mexico are involved in the analysis. Space Weather effects are most prominent during geomagnetic disturbances. The aim of this study was to estimate the ionosphere state over Mexico under quiet and disturbed geomagnetic conditions to reveal if there is any local specifics of the ionosphere behaviour over the region.

2. Reconstruction of missed data

The foF2 values were reconstructed with use of the median value of the equivalent slab thickness of the ionosphere, τ(med), applying the method [2] and according to the algorithm:

$$\mathrm{foF2(rec)} = 897 \cdot \sqrt{\mathrm{NmF2(rec)}} \qquad (1)$$

$$\mathrm{NmF2(rec)} = \frac{\mathrm{TEC(obs)}}{\tau\mathrm{(med)}} \qquad (2)$$

NmF2 is maximum electron concentration in the F2-layer. The absolute values of the equivalent slab thickness τ(obs) were calculated for the stations in the close regions (Eglin, U.S.A. and Ramey, Puerto Rico) that have both measurements TEC and foF2.

$$\tau\mathrm{(obs)} = \frac{\mathrm{TEC(obs)}}{\mathrm{NmF2(obs)}} \qquad (3)$$

Figure 1 illustrates the location of the stations. Further, τ(med) was calculated for both stations and applied with TEC measured in Mexico, TEC(obs).

Figure 1. Map of stations locations.

Thus, the missing foF2 in Mexico was reconstructed.

The difference in τ(med) by two mentioned stations confirms that still local ionosonde measurements are needed. However, inclusive this difference the method helps to estimate foF2 over the adjacent regions. This was proven by tests [3]. Figure 2 provides an example of reconstructed parameter (rec) compared to a) foF2 obtained from by the IRI-model, b) to median foF2 (med), c) foF2 measured by ionosonde (obs). The example illustrates that foF2 reconstructed using local TEC measurements has better agreement with experimental data. The values were compared for the period of geomagnetic storm characterized by minimum Dst-index value of -98 nT on September 9th, 2015.

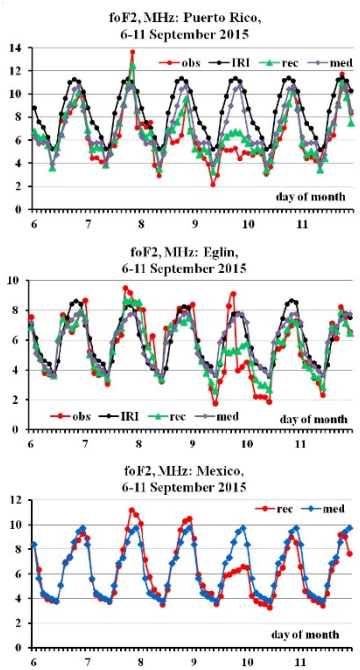

Figure 2. Comparison of reconstructed foF2 with median, IRI-model and observational values.

3. Regular variations of parameters.

Diurnal and seasonal patterns in TEC and foF2 behaviour over Mexico were obtained. The diurnal variation of TEC over Mexico corresponds to climatological models of TEC [4]. In most cases, the main diurnal maximum in TEC is observed near 14 hours local time (LT) or 20 hours universal time (UT), which confirms the existing understanding of TEC diurnal behaviour for these latitudes [5]. It was revealed that in many cases there is a second maximum in the diurnal trend at night hours. The probability of night-time TEC enhancements in Mexico is very high. For example, during 2015 on average, it reached about 54 % according to the data of UCOE station (lat 19°48' N, lon 101°41' W). The effect was most pronounced in December (74% of observed days), April (67%), May and August (61%). November had less observed number of days with night-time TEC enhancements (37%). To sum up, the TEC night-time enhancements are the characteristic feature in a daily TEC course over the Mexican region. No dependence of the enhancements on Space Weather disturbances was found.

Figure 3 shows the seasonal trend in TEC and NmF2-analog values for Mexico City (19.3°N, 99.1°W) in 2004 and 2015 (both years are found on the descending half of solar cycles 23 and 24 with F10.7-index varying within (80-180) s.f.u. in 2004 and (80 – 170) s.f.u. in 2015. Two maximums in the behaviour of both parameters are pronounced: in March and September in 2004 and in April and October in 2015. The October 2015 maximum in TEC values is much less obvious than in NmF2 values.

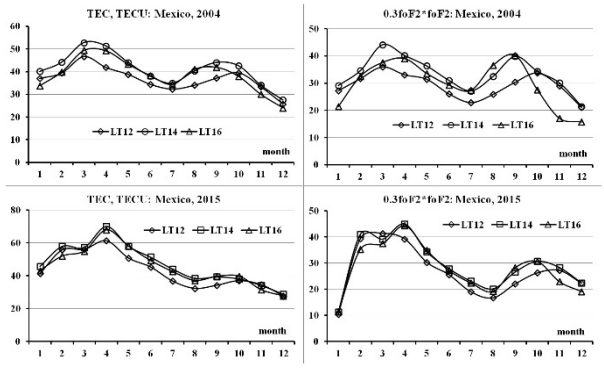

Figure 3. Illustration of seasonal patterns over Mexico.

4. TEC behaviour during disturbances.

Analyzing the statistics of TEC behavior revealed that the peculiarity of TEC over Mexico is the presence of strong positive enhancements sometimes not related to geomagnetic disturbances. It was found earlier in work [6] that the daytime large-scale enhancements of TEC often occur in the U.S. territory and less frequently in other regions of the Earth. This study confirms that the same effects occur at lower latitudes of North American continent, over Mexico. In the work [6] the Utah State University Time Dependent Ionospheric Model (TDIM) was used to model ionospheric conditions. The present study was based on TEC derived from local receivers and from GIM technology. The foF2 data was reconstructed for the periods with available ionosonde and local TEC data. The example of TEC enhancement during the disturbance of November 6th, 2001 characterized by minimum Dst-index value of -292 nT is presented in Figure 4. The results are for Mexico City station. The values foF2(rec) were reconstructed with TEC(obs) over Mexico and τ(med) at Eglin. Plasma frequency data, fne(sat), obtained at CHAMP and DSMP low-orbit salettiles are shown to confirm the sign of the disturbance. The altitudes of orbits in November 2001 were ~440 km for CHAMP and ~840 km for DMSP. The increase of TEC and foF2 values over their medians occurred during all the day of November 6th, 2001 and the first half of November 7th, 2001. During the night universal time (0-1.5 UT) the significant fne(sat) increase over its median was observed for both satellites. The significant increase was also seen at approximately 13 UT by CHAMP data, while it was the weak increase by

DMSP data. It is the evidence that the main growth of ionization occurred probably in the topside ionosphere profile. Sometimes positive TEC enhancements can also occur on quiet geomagnetic background.

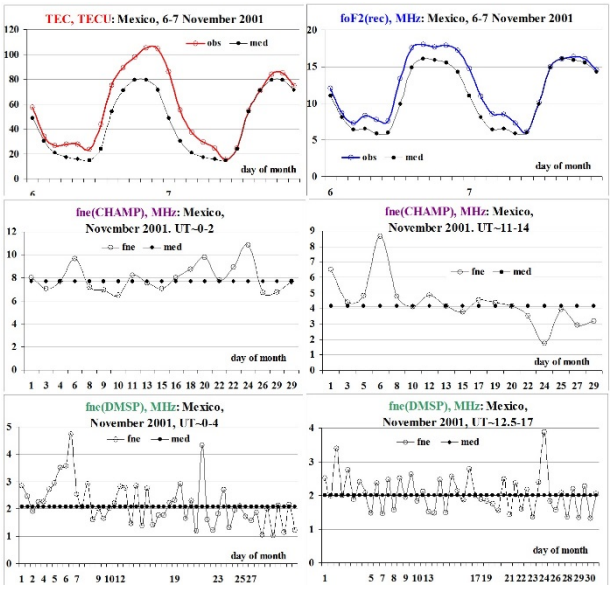

Figure 4. The ionospheric parameters behaviour for Mexico station in November, 2001.

5. Conclusion

Since 2015 the continuous monitoring of TEC variations over the territory of Mexico is performed by the Mexican Space Weather Service (SCiESMEX). The Service works on the project of the ionosonde installation in Mexico. However, currently the critical frequency of F2 ionospheric layer that characterizes the maximum concentration NmF2 is missing at this region. To reconstruct missing data the method [2] was applied, in particular foF2 values were reconstructed using TEC measured over Mexico and equivalent slab thickness of the ionosphere measured in the adjacent to Mexico regions.

Regular patterns of the diurnal and seasonal TEC and foF2 variations were obtained in base of past statistics and real-time observations over Mexico. The Space Weather impact over Mexico was estimated with TEC. Regular behaviour of parameters corresponds to existing climatological models. During disturbances the peculiarity of TEC over Mexico is the presence of strong positive enhancements.

6. Acknowledgements

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