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Ionospheric response under the influence of the solar eclipse occurred on 20 March 2015: Importance of autoscaled data and their assimilation for obtaining a reliable modeling of the ionosphere

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ABSTRACT

This paper wants to highlight how the availability of measurements autoscaled at some reference ionospheric stations, and their assimilation by ionospheric models, was of crucial importance in determining, during the solar eclipse conditions occurred on 20 March 2015, a reliable representation of the ionosphere. Even though the solar eclipse falls in the recovery phase of the St. Patrick geomagnetic storm started on 17 March 2015, its influence on the ionospheric plasma seems undeniable. The reference ionospheric stations considered here are those of Rome (41°.8′ N, 12°.5′ E), and Gibilmanna (37°.9′ N, 14°.0′ E), Italy. Specifically, in a time interval including that of the eclipse, the electron density profiles autoscaled by the Automatic Real-Time Ionogram Scaler with True-height (ARTIST) system at San Vito (40°.6′ N, 17°.8′ E), Italy, which are here considered as the truth profiles, were compared with both the electron density profiles calculated by the IRI-SIRMUP-Profiles (ISP) model, after assimilating data recorded at Rome and Gibilmanna, and the electron density profiles provided by the IRI-CCIR model. The ISP and IRI-CCIR performances were then evaluated in terms of the root mean square errors made on the whole electron density profiles. The three-dimensional (3-D) electron density mappings of the ionosphere provided by ISP and IRI-CCIR models were also considered as the ionospheric environment by the ray tracing software tool IONORT to calculate quasi-vertical synthesized ionograms over the short radio link San Vito – Brindisi (40°.4′ N, 17°.6′ E), Italy. The corresponding synthesized values of *fo*F2 and *fx*F2, obtained by IONORT-ISP and IONORT-(IRI-CCIR) procedures, were compared with those autoscaled by ARTIST from the vertical ionograms recorded at the truth site of San Vito. Some examples of IONORT-ISP and IONORT-(IRI-CCIR) synthesized ionograms are shown and discussed. Finally, comparisons in terms of *fo*F2 deduced by long-term prediction and nowcasting maps are also shown. The results achieved in this work demonstrate how the assimilation of autoscaled data into the ionospheric models turned out to be valuable in providing a better representation of the ionospheric electron density under very unusual conditions.

1. Introduction

During a solar eclipse event, the solar disk is obscured by the Moon in such manner that the photochemical activity in the ionosphere is subject to a rapid decrease, thus reaching the levels observed during night time. This gives rise to many different physical phenomena which are well described in the extensive literature gathered in the last decades. Several investigations were indeed conducted to study different ionospheric effects caused by solar eclipse conditions: the detection and enhancement of acoustic gravity waves (Frost and Clark, 1973; Šauli et al., 2006, 2007; Koucká Knížová and Mošna, 2011), and induced gravity waves (Chimonas, 1970; Bertin et al., 1977; Chimonas and Hines, 1971; Fritts and Luo, 1993; Altadill et al., 2001, 2004; Zerefos et al., 2007; Gerasopoulos et al., 2008; Manju et al., 2014; Gang et al., 2015); a decrease of total electron content (Salah et al., 1986; Afraimovich et al., 1998; Baran et al., 2003; Jakowski et al., 2008; Krankowski et al., 2008; Le et al., 2008, 2009; Ding et al., 2010; Momani, and Sulaiman, 2011; Kumar et al., 2013); an increase of the top frequency (*ft*Es) of the sporadic E (Es) layer (Es) (Datta, 1972, 1973; Chen et al., 2010; Yadav et al., 2013), but also its decrease (Minnis, 1955; Stoffregen, 1955); a persistence of the Es layer without any variation of the corresponding intensity (Pezzopane et al., 2015); decreases of the critical frequencies of the ordinary mode of propagation

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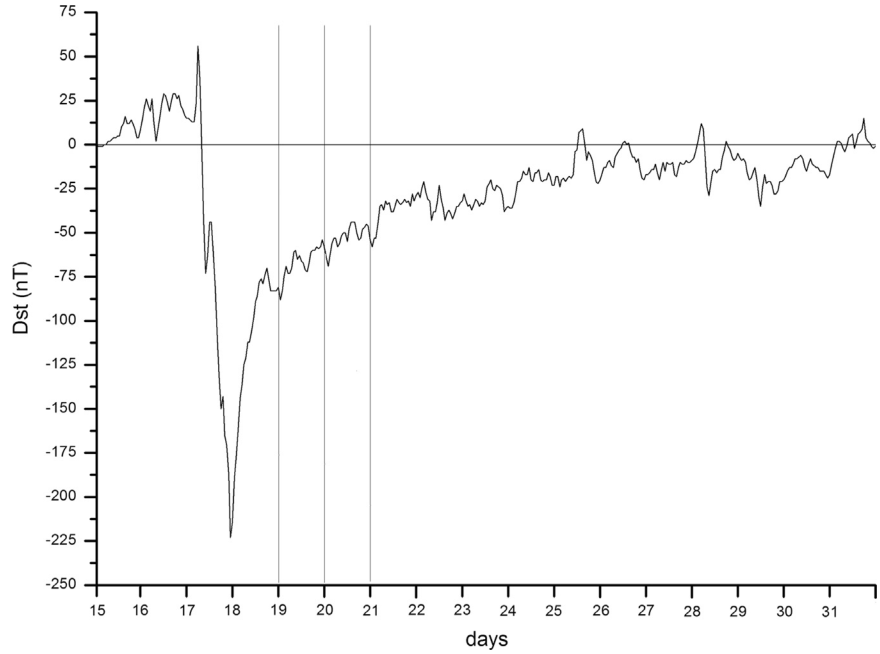

Fig. 1. Dst index recorded from 15 March to 31 March 2015. The three thin vertical lines highlight respectively the day before, during and after the solar eclipse event.

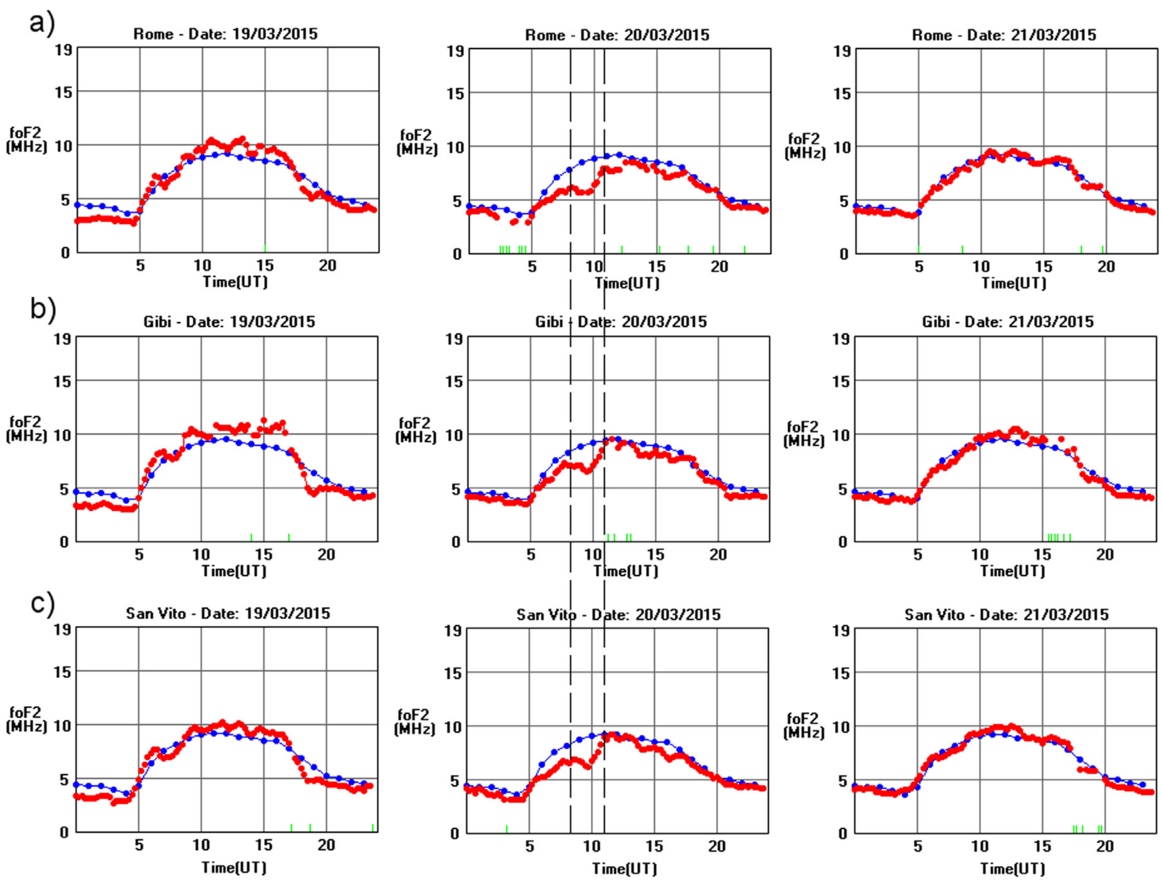

Fig. 2. The *fo*F2 monthly median values predicted by the SIRM long-term prediction model (blue dots) and the *fo*F2 autoscaled values (red dots) for a) Rome, b) Gibilmanna, and c) San Vito, on 19, 20, and 21 March 2015. The dashed vertical lines highlight the start (∼08:30 UT) and the end (∼10:30 UT) times of the partial solar eclipse occurred on 20 March 2015, as recorded at the ground. The green vertical hyphens that from time to time appear at the bottom of the plots mean that the ionogram was recorded but the autoscaling system did not give any value as output.

*fo*E, *fo*F1, and *fo*F2 of the E, F1, and F2 layers, respectively, (Hunsucker, 1965; Cheng et al., 1992; Adeniyi et al., 2007; Domnin et al., 2013), as well as, albeit rarely, an increase of *fo*F2 (Evans, 1965).

In this investigation *fo*F2 is the characteristic considered to highlight the disturbed ionospheric conditions caused by the solar eclipse event occurred on 20 March 2015. It is worth highlighting that this solar eclipse occurred during the St. Patrick geomagnetic