10th European Space Weather Week, 18-22 November 2013, Antwerp, Belgium

Performance of IRI-SIRMUP-P mapping of the ionosphere for disturbed periods

M. Pezzopane[1], M. Pietrella[1], A. Pignatelli[1], B. Zolesi[1], Lj.R. Cander[2]
[1]*Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*
[2]*STFC, Rutherford Appleton Laboratory, Chilton, OX11 0QX, UK*
michael.pezzopane@ingv.it

Introduction

This paper describes the three-dimensional (3-D) electron density mapping of the ionosphere given as output by the assimilative IRI-SIRMUP-P (ISP) model for three different geomagnetic storms. Results of the 3-D model are shown by comparing the electron density profiles given by the model with the ones measured at two testing ionospheric stations: Roquetes (40.8N, 0.5E), Spain, and San Vito (40.6N,17.8E), Italy. The reference ionospheric stations from which the autoscaled foF2 and M(3000)F2 data as well as the real-time vertical electron density profiles are assimilated by the ISP model are those of El Arenosillo (37.1N,353.3E), Spain, Rome (41.8N,12.5E), and Gibilmanna (37.9N,14.0E), Italy (Fig. 1). Overall, the representation of the ionosphere made by the ISP model is better than the climatological representation made by only the IRI-URSI and the IRI-CCIR models. However, there are few cases for which the assimilation of the autoscaled data from the reference stations causes either a strong underestimation or a strong overestimation of the real conditions of the ionosphere, which is in these cases better represented by only the IRI-URSI model. This ISP misrepresentation is mainly due to the fact that the reference ionospheric stations covering the region mapped by the model turn out to be few, especially for disturbed periods when the ionosphere is very variable both in time and in space and hence a larger number of stations would be required. The inclusion of new additional reference ionospheric stations could surely smooth out this concern.

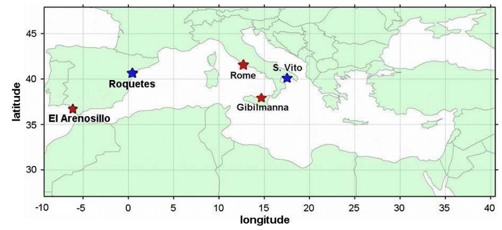

Fig. 1. Map of the central Mediterranean area under study. Red stars represent the ionospheric stations considered as input for the model. Blue stars represent the ionospheric stations considered as test sites.

Analysis and Results

In order to test the model for disturbed ionospheric conditions, the three geomagnetic storms that occurred from 23 to 24 April 2008 (max Kp = 5), from 5 to 8 April 2010 (max Kp = 8), and from 2 to 4 May 2010 (max Kp = 6) were considered. These periods were particularly selected to test the model because most of the autoscaling computations made both by ARTIST at El Arenosillo, Roquetes, and San Vito, and by Autoscala at Rome and Gibilmanna were available. In particular, the attention was focused on the positive and negative ionospheric phases characterizing the disturbed periods under study, as shown in Fig. 2.

The results of the test are shown in Figs. 3-4 where the electron density profiles obtained by the IRI-URSI and the IRI-CCIR procedures, by the ISP procedure, and by the ARTIST system are compared. The IRI-URSI and IRI-CCIR profiles were calculated to a maximum height of 1000 km, using IRI-2007 with the foF2 storm model option checked "on" and all the other parameterizations selected as default, while the maximum height of the ISP profiles is equal to 400 km because Autoscala models the topside as a parabolic layer ending right at that height.

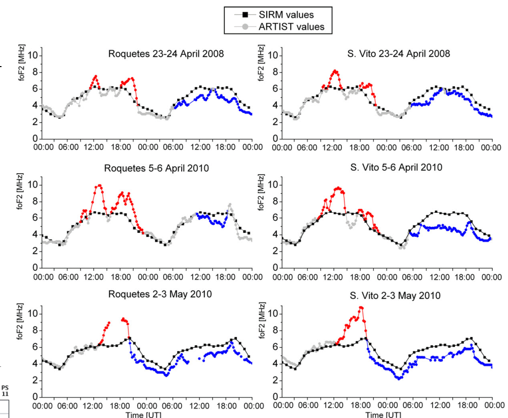

Fig. 2. ARTIST foF2 values (grey circles), as obtained by the 15-min ionograms recorded at Roquetes and San Vito from 23 to 24 April 2008, from 5 to 6 April 2010, and from 2 to 3 May 2010, compared to the corresponding foF2 hourly median values (black squares) predicted by the SIRM model, both at Roquetes and at San Vito, and here assumed as quiet-day values. The positive and negative ionospheric phases are highlighted by red and blue circles respectively.

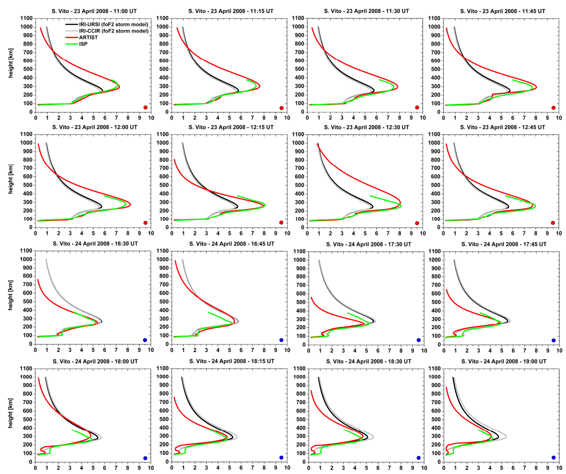

Fig. 3. Comparison among some profiles obtained at S. Vito on 23 and 24 April 2008 by ISP (green), ARTIST (red), IRI-CCIR (gray) and IRI-URSI (black). Red or blue circles close to the lower right angle of the plot identify profiles belonging to the positive or negative ionospheric phase respectively.

Fig. 5.

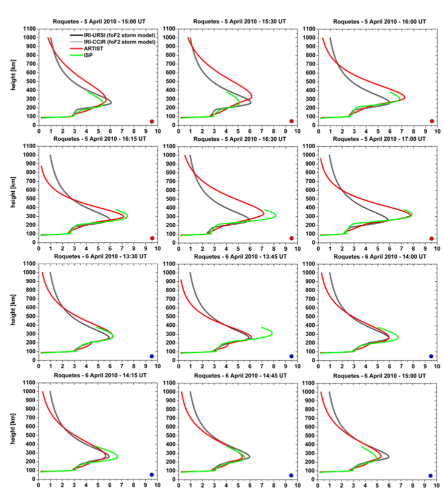

Fig. 4. Same as Fig. 3 for profiles obtained at Roquetes on 5 and 6 April 2010.

Summary and Discussion

Figs. 3–4 show that the specification of the ionosphere made by the ISP model is far better than the climatological specification made by only either the IRI-URSI or the IRI-CCIR models. For all the three geomagnetic storms considered in this study, the ISP model can follow pretty reliably the positive and negative phases affecting the ionosphere, both at S. Vito and at Roquetes. The IRI-URSI and the IRI-CCIR models can represent properly only the negative ionospheric phase characterizing the 6 April 2010. On the contrary, Pezzopane et al. (2011) showed that for geomagnetically quiet days, mostly for quasi-stationary ionospheric conditions, the electron density profiles extracted from the IRI-URSI and from the ISP matrixes were pretty similar, and both of them were in good agreement with the electron density profile measured by ARTIST.

This suggests that at the moment for the IRI model the inclusion of the foF2 storm model is not sufficient to well represent the real conditions of a disturbed ionosphere. On the other hand, Figs. 3–4 show that the assimilation by IRI of data measured at some reference ionospheric stations is very important to give as output a reliable image of the ionosphere.

However, focusing our attention on some plots, we can see that there are some cases for which the ISP profiles strongly underestimates (see the 5 April 2010 at 15:30 UT of Fig. 4) or strongly overestimates (see the 5 April 2010 at 16:30 UT and the 6 April 2010 at 13:45 UT of Fig. 4) the profile measured by ARTIST. In reality, some ISP overestimations are artificial and rather due to an underestimation made by the autoscaling performed by ARTIST that tends to cut off the ionogram trace when this is weak, as it is the case of the ionogram recorded at Roquetes the 5 April 2010 at 16:30 UT (Fig. 5). With regard to the other overestimations and underestimations that are computed more generally by the ISP model, these are mainly caused by the large control that the foF2 values assimilated by ISP have in the calculation of Reff. In fact, if for example the autoscaled foF2 values are lower than the long-term foF2 values given by SIRM, then the calculated Reff will be lower than the smoothed sunspot number R12 that is used by SIRM to calculate the foF2 long-term prediction. As a consequence, the foF2 and M(3000)F2 values of the grid, calculated by the SIRMUP procedure using this value of Reff, will be overall lower than those given by SIRM, and not only in correspondence of the points of the grid from which the autoscaled foF2 values were assimilated. It means that in this case, if in some regions of the grid the real foF2 values tend to be close to the long-term values, the ISP model for those regions will underestimate the real conditions of the ionosphere. This is just what happens at Roquetes on 5 April 2010 at 15:30 UT (see Fig. 4) where the underestimation made by the ISP model is caused by a low value of Reff calculated in virtue of the low foF2 values autoscaled at Rome and Gibilmanna. Vice versa, if for example the autoscaled foF2 values are higher than the long-term foF2 values given by SIRM, the calculated Reff is higher than the smoothed sunspot number R12 that is used by SIRM to calculate the foF2 long-term prediction. As a consequence, the foF2 andM(3000)F2 values of the grid calculated by the SIRMUP procedure using this value of Reff, will be overall higher than those given by SIRM, and not only in correspondence of the points of the grid from which the autoscaled foF2 values were assimilated. It means that in this case, if in some regions of the grid the real foF2 values tend to be close to the long-term values, then for those regions the ISP model will overestimate the real conditions of the ionosphere. This is just what happens at Roquetes on 6 April 2010 at 13:45 UT (see Fig. 4), where the overestimation made by the ISP model is caused by a high value of Reff calculated in virtue of the high foF2 value recorded at El Arenosillo.

This kind of problem is of course more likely to happen for disturbed conditions, when the probability to have a very variable ionosphere both in time and in space is greater. The inclusion of additional reference ionospheric stations covering more and more the region mapped by the model could surely smooth out this misrepresentation.