Effect of Solar Eclipse of March 20, 2015 on the Ionosphere

A. Ippolito1, A. Settimi1, C. Scotti1, D. Sabbagh1,2, V. Sgrigna2

1 Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy.
2 Università Roma Tre, Roma, Italy.

The effect on the ionosphere of solar eclipse of March 20, 2015 on different ionospheric layers has been studied, using the vertical ionospheric soundings from the ionosondes of Rome, Gibilmanna and San Vito dei Normanni. The response of the critical frequencies fF2 and fE, and fE, have been investigated during the solar eclipse. The DuCharme and Petrie's formulation used to estimate fF2 has been corrected taking into account the decreased solar irradiance. This effect has been modeled by a Solar Obscuration Factor (SOF) and comparison with experimental values has been performed. A further study on the occurrence of the Sporadic E layer during the eclipse is here presented. As reported in literature, sporadic E layer appears during the eclipse, if the ionograms for 3 days before and 3 days after are analysed. When a wider set of days before and after the eclipse event are taken into account this phenomenon does not appear so clear. The behaviour of a regional adaptive and assimilative 3D ionospheric model has been tested as well, assimilating plasma frequency profiles fN(h).

Through the study of the model behaviour in such particular condition we could introduce corrections to fF2 and fE formulation, improving the performances of our adaptive ionospheric regional 3Dmodel.

Taking into account solar activity and geomagnetic coordinates of a specific site, the trend of the critical frequency F1 is described by the semi-empirical Du Charme’s formula (Du Charme et al., 1973). When an extraordinary event, such as a solar eclipse, occurs, this formula is not able to describe the fF2 variations, as shown in figure 2. A correction factor in order describe the decrease of fF2 in such events, has been introduced. A SOF (Solar Obscuration Factor) has been implemented in the Du Charme’s formula, which consider the Sun’s obscurance due to the transit of the Moon. In figure 1 we report the SOF factor during the solar eclipse of March 20th 2015 over the three considered ionosondes, calculated in a similar way as proposed by Möllmann and Vollmer (2006). The vertical ionograms of March the 20th 2015, from 8:15 AM (UTC) to 11:00 AM (UTC) have been analysed and a comparison between the observed fF2 values and the predicted ones –by the Du Charme formula without the SOF correction- is presented of figure 2. As can be seen in the three panels, applying the SOF correction to Du Charme’s formula, the estimated values of fF2 present a close agreement with the measured ones.

In figure 3 are reported the maps of estimated fF2 taken every 15 minutes over the Italian region, when the eclipse occurs. In figure 4 we show time behaviour of the observed values fF2Measured in the three ionospheric stations of Rome, Gibilmanna and San Vito. fF2Measured is the measured fF2 values deduced from the ionograms manual scaling. In the same figure is shown with black dots fF2SOF which is a value representing the temporal evolution of fF2Measured as it would be expected if the eclipse was not there. The fF2SOF values are derived from lowering the monthly median by a factor, chosen so as to minimize the standard deviation between the observed values and those measured, considering the ionograms recorded before and after the eclipse. Then the difference d = fF2Measured – fF2SOF, in ionospheric stations of Rome, Gibilmanna were calculated and shown in figure 4. These differences are reported with red dots in figure 5 as a function of the SOF performing quadratic regression. In figures 6 (a, b and c) a strong agreement of the expected fF2 values applying the SOF correction, can be seen with fF2Measured.

In panels (a) of figures 8 and 9 we report the analysis of received echo in the 3 days previous and next to the eclipse, while panels (b) report data related to 10 days before and 10 days after the solar eclipse. In a red color scale are reported the recorded values proportional to the received energy in the 3.8-4.2 MHz band. The brightest reds are referred to the highest energy values. The green points represent the values recorded on 2015 the 20th, on the day of the solar eclipse. The vertical blue lines on the plots represent respectively the start and the end of the solar eclipse. According to literature (Chen et al., 2010; Yadav et al., 2013) sporadic E layer appears during the solar eclipse (panels (a) of figures 8 and 9) when the ionograms for 3 days before and 3 days after the eclipse were analysed. When a wider set of days before and after the eclipse event are taken into account this phenomenon does not appear so clear as can be seen from panels (b) of figures 8 and 9.

References: