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

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The effect on the ionosphere of solar eclipse of March 20, 2015 on different ionospheric layers is studied. The response of the critical frequencies foF1 and foF2, related to the ionospheric F1 and F2 regions have been investigated during the solar eclipse, using the vertical ionospheric soundings from the ionosondes of Rome, Gibilmanna and San Vito dei Normanni. A further study on the occurrence of the Sporadic E layer during the eclipse hours is here presented.

The trend of the critical frequency F1 is described by the semi-empirical Du Charme's formula (Du Charme et al., 1970) :

$$foF_1 = f_s \cos^{\eta}\chi$$

Through this relationship the changes of foF1 during the day can be calculated for a particular geographic position, taking into account solar activity and geomagnetic coordinates of the site. However this is not enough to describe the trend of the F1 critical frequency when an extraordinary event, such as a solar eclipse, occurs, as can be seen in the example of figure 1, in which the data of foF1 manually scaled from the ionograms obtained from the Ionosonde in Rome have been compared to the foF2 values calculated using Du Charme's formula. An additional factor to describe the fluctuation of foF1 in such events as the observed eclipse, has been introduced. Indeed a SOF (Solar Obscuration Factor) has been implemented in the Du Charme's formula in order to take into account the Sun's obscuration due to the transit of the Moon.

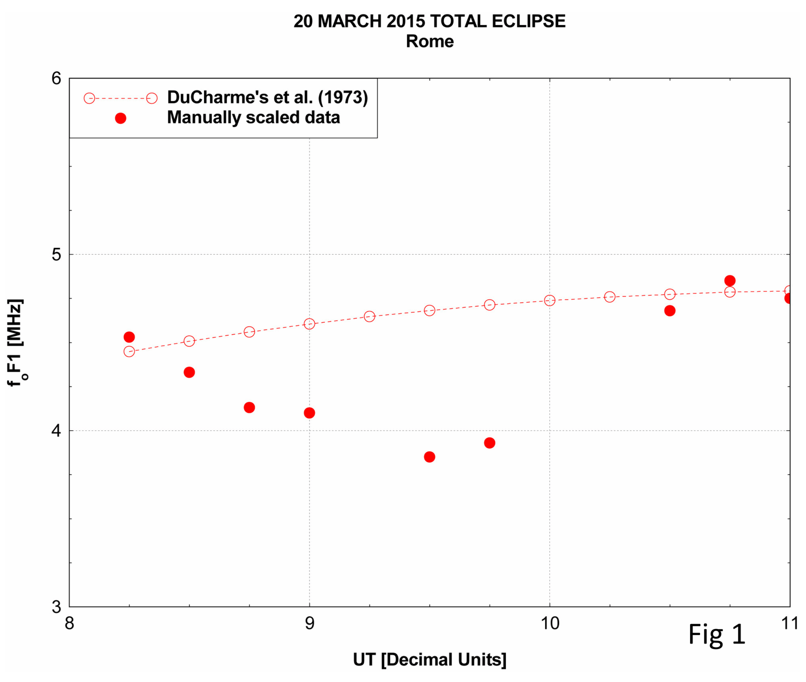

Fig 1

$$SOF = \frac{2}{\pi}\left[\cos^{-1}\sqrt{d^2+\frac{a(t)^2}{4}} - \sqrt{d^2+\frac{a(t)^2}{4}}\sqrt{1-\left(d^2+\frac{a(t)^2}{4}\right)}\right].$$

Where $a(t) = A\left[2\left(\frac{t-t_s}{t_e-t_s}\right)-1\right]$; $A = 2\sqrt{1-d^2}$ and d is evaluated by solving $M = \frac{2}{\pi}\left[\cos^{-1} d - d\sqrt{1-d^2}\right]$.

Du Charme's formula became:

$$foF_1 = (1 - SOF)^{\eta} f_s \cos^{\eta}\chi$$

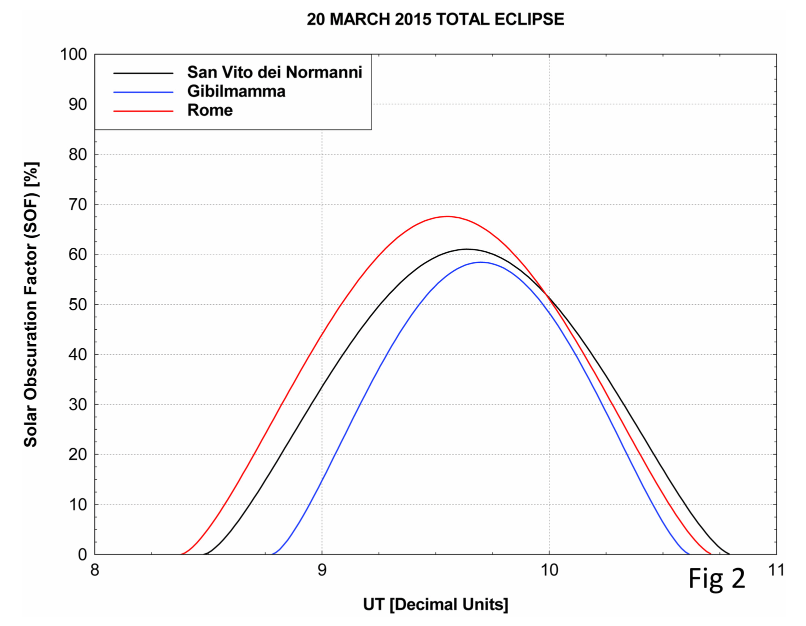

Fig 2

The vertical ionograms of March the 20th 2015, from 8:15 AM (UTC) to 11:00 AM (UTC) have been analised. In figure 2 we report the SOF factor during the 20th March 2015 eclipse over the three considered ionosondes. The expected foF1 values from the implemented Du Charme's formula have been compared to the measured foF1 values manually scaled from the vertical ionograms taken by the ionosondes of Rome and Gibilmanna, and to the automatically scaled values of foF1 provided by ARTIST from the vertical ionograms of the San Vito dei Normanni ionosonde.

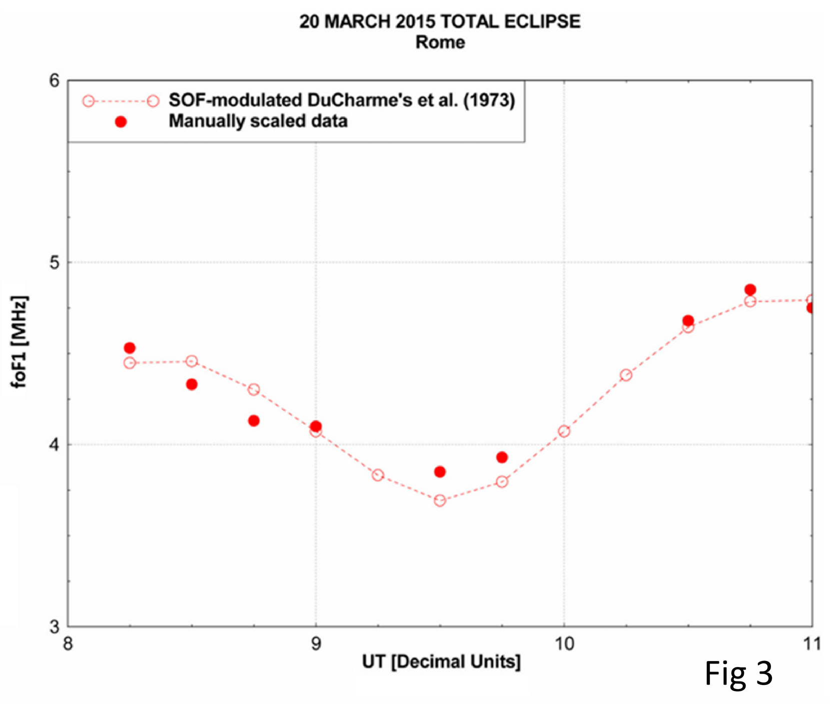

Fig 3

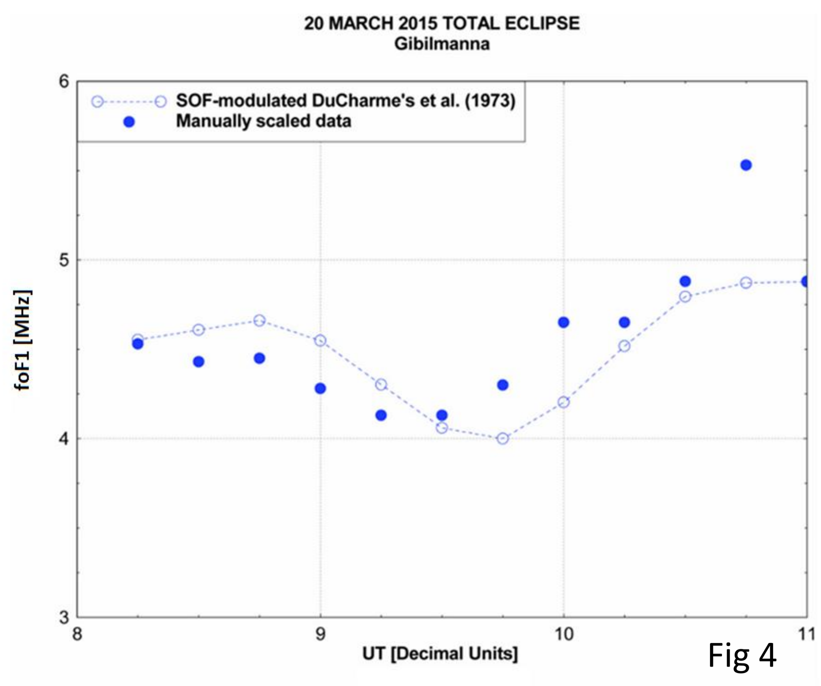

Fig 4

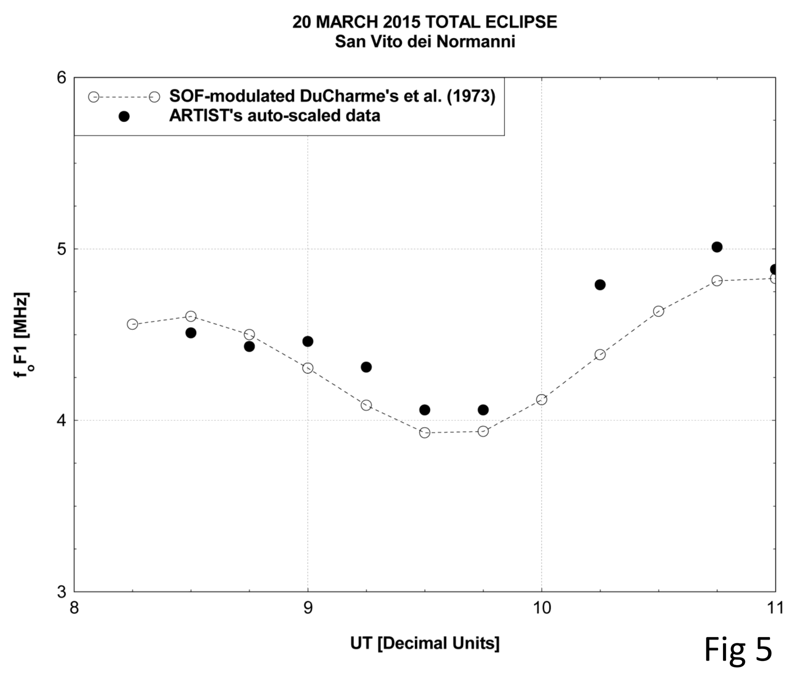

Fig 5

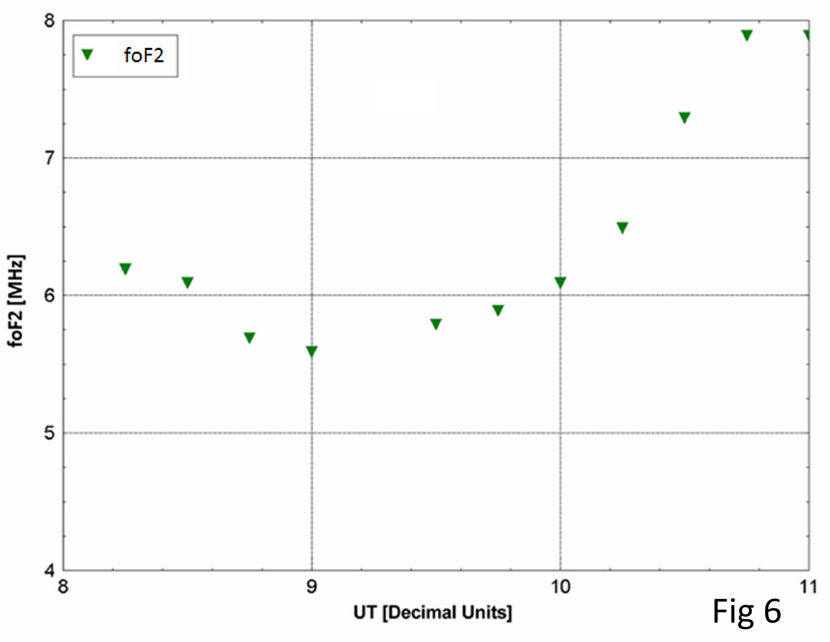

Fig 6

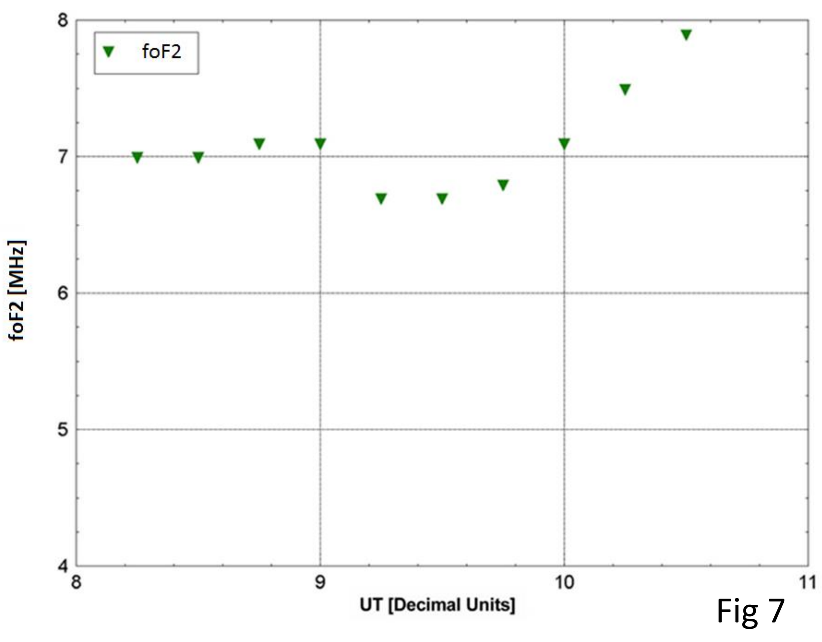

Fig 7

As can be seen in figures 3, 4 and 5, the comparison demonstrates a good agreement between the expected FoF1 values obtained from the modified Du Charme's formula and the ones observed. During the solar eclipse, a decrease of foF2 can be also seen from the values manually scaled from the ionograms obtained by the ionosondes of Rome and Gibilmanna, and plotted in figures 6 and 7.

A study on the occurrence of the Sporadic E layer during the solar eclipse is also presented, using data from Rome and Gibilmanna ionosondes. In panels (a)s of figure 8 and 9 we report the analysis of the backscatter eco received by the ionosondes in the 3 days previous and next to the eclipse, while in panels (b)s of the same figures we consider data related to 10 days before and 10 days after the solar eclipse. In a red color scale are reported the values recorded, which are proportional to the received backscattered 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, the day of the solar eclipse. The vertical blue lines on the plots represent respectively the start hour and the end hour of the solar eclipse. As reported in literature (Chen et al., 2010; Yadav et al., 2013) sporadic E layer appears during the solar eclipse, as can be deduced from panels (a)s of figures 8 and 9, where 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 were taken into account, as we made in panels (b)s of the same figures, this phenomenon does not appear so clear.

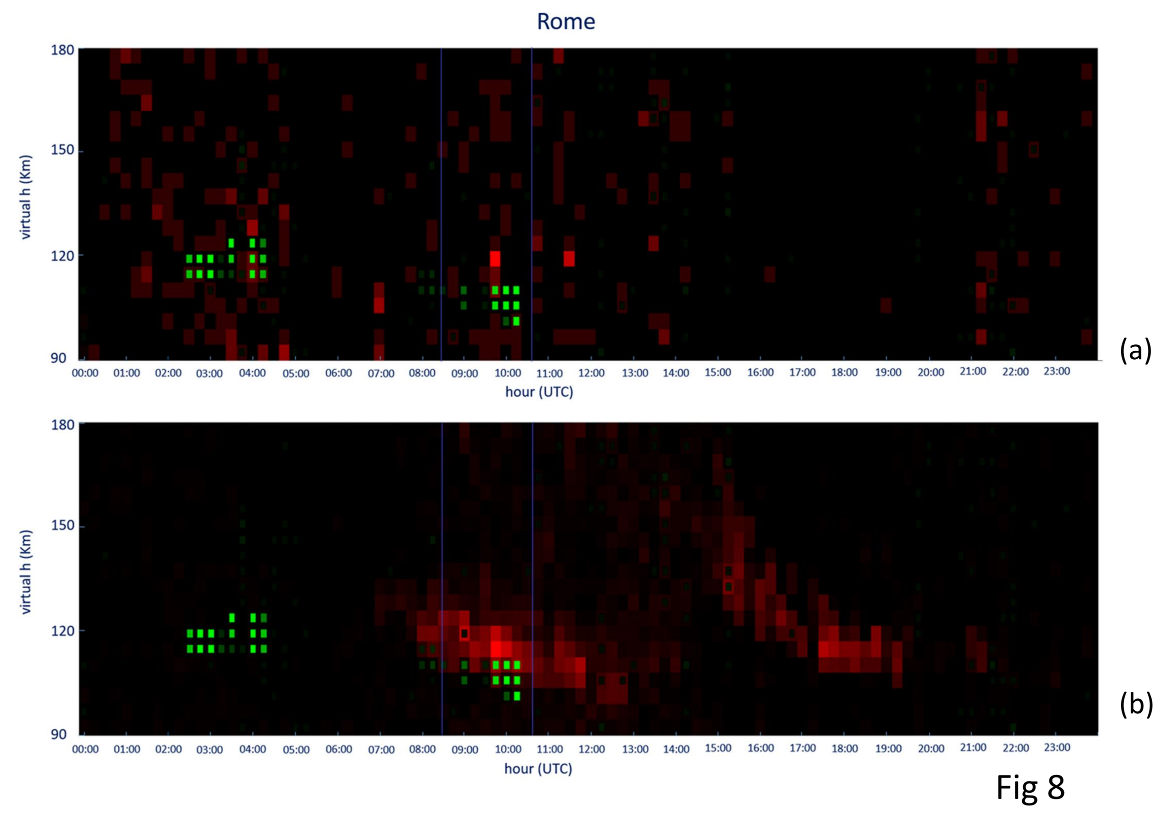

Fig 8

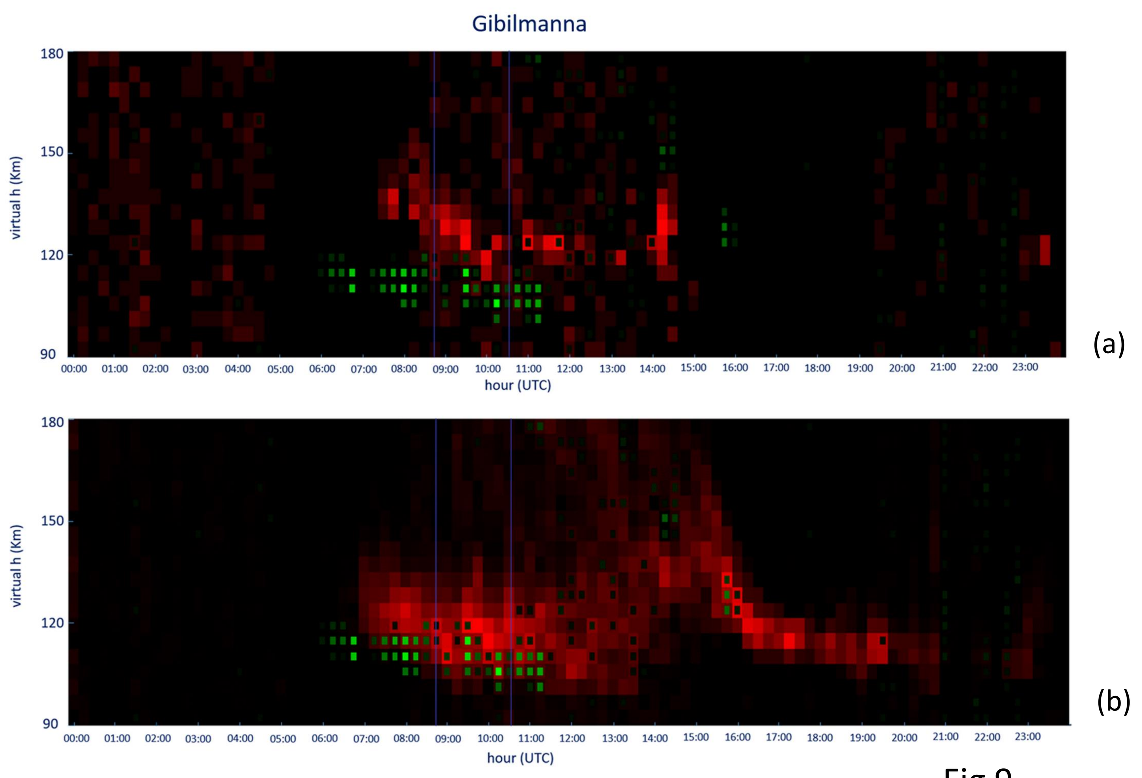

Fig 9

The behaviour of a regional adaptive and assimilative 3D ionospheric model has been tested during the solar eclipse, when it assimilates plasma frequency profiles from Roma and San Vito dei Normanni Digisondes. In figure 10 we report the root mean square deviations (RMSDs) obtained beetween observed and modeled plasma frequency profiles over Gibilmanna. Red arrows highlight cases of bad profile inversion by Autoscala software. This point out that the availibility of reliable Ne(h) is a relevant problem in models testing. In figure 11 we report comparisons between observed profiles (green) and modeled ones (blue) over Gibilmanna. In panel (a) the observed profile is obtained from standard Autoscala software, when in panel (b) they are obtained from a modified version of Autoscala software, where correct values for foE are ingested. In this case we can see that the model is able to fit better the observation.

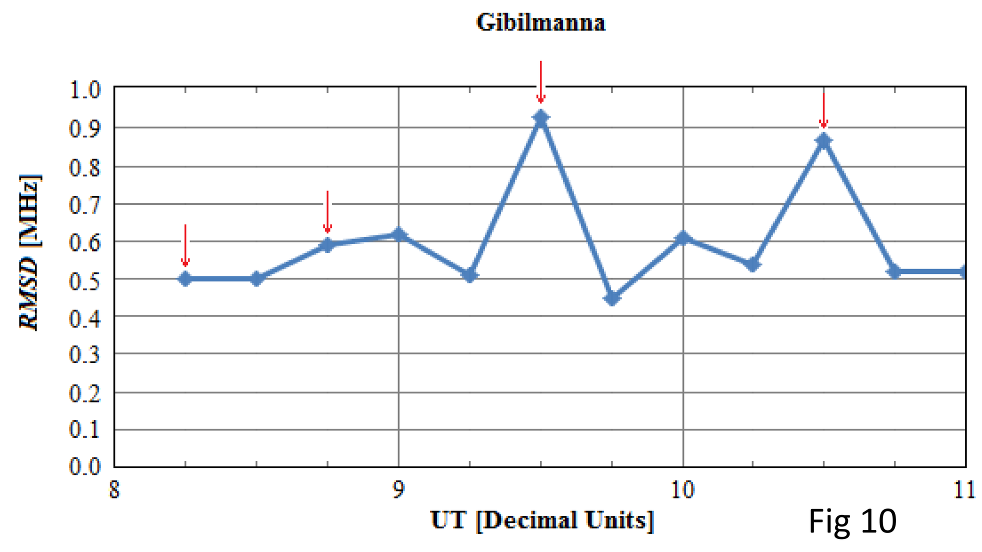

Fig 10

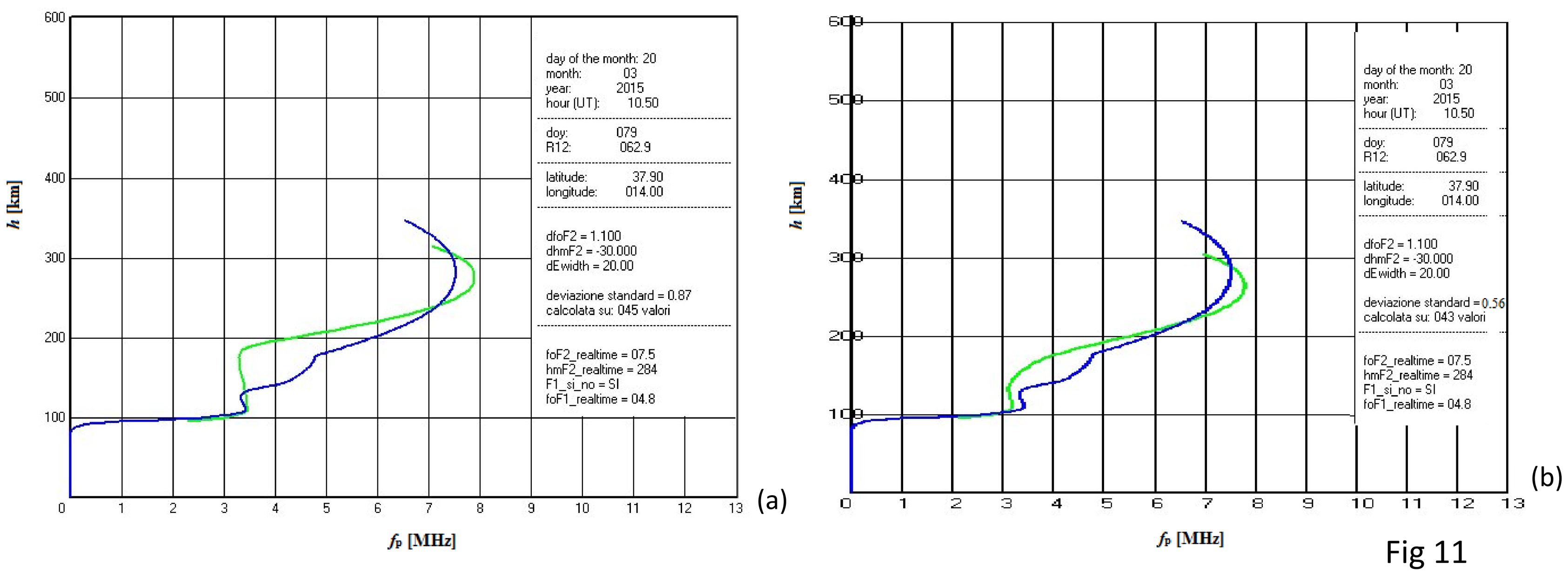

Fig 11