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 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 f_oF_1 and f_oF_2 have been investigated during the solar eclipse. The DuCharme and Petrie's formulation used to estimate f_oF_1 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 $f_p(h)$. Through the study of the model behaviour in such particular condition we could introduce corrections to f_oF_2 and f_oF_1 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 f_oF_1 variations, as shown in figure 2. A correction factor in order describe the decrease of f_oF_1 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 obscuration due to the transit of the Moon. In figure 1 we report the SOF factor during the 20th March 2015 eclipse over the three considered ionosondes, calculated in a similar way as proposed by Mollmann 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 f_oF_1 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 f_oF_1 present a close agreement with the measured ones.

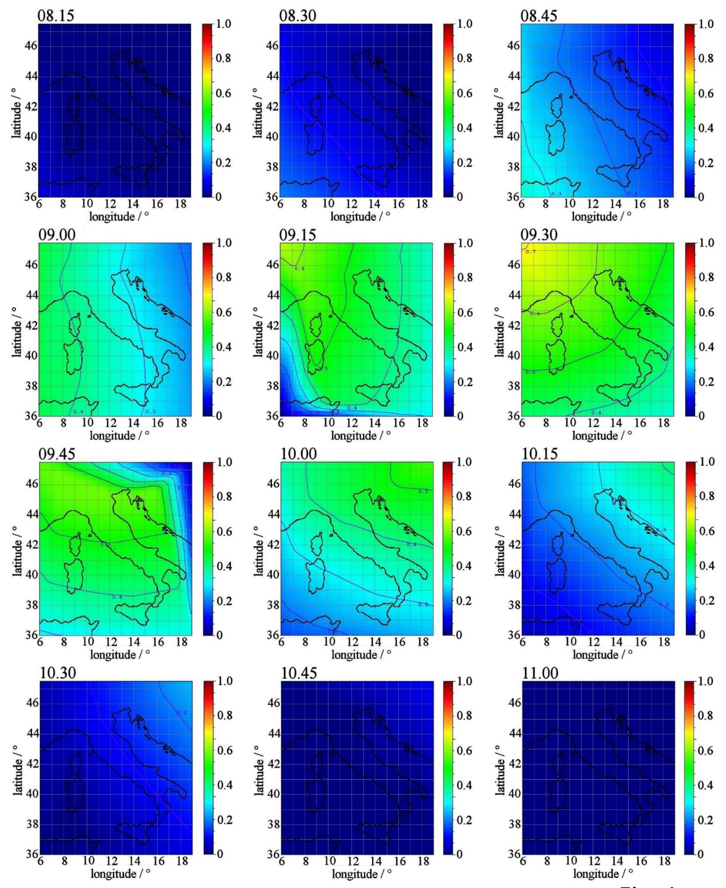

Fig. 1

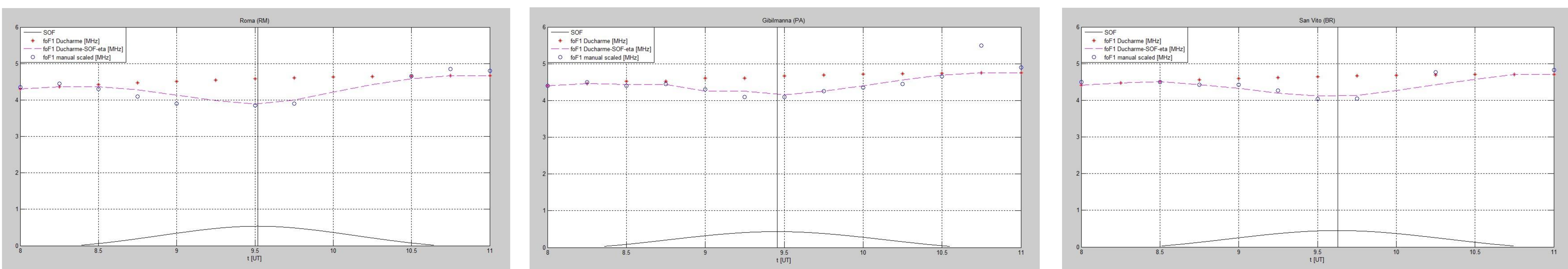

Fig. 2 (a) (b) (c)

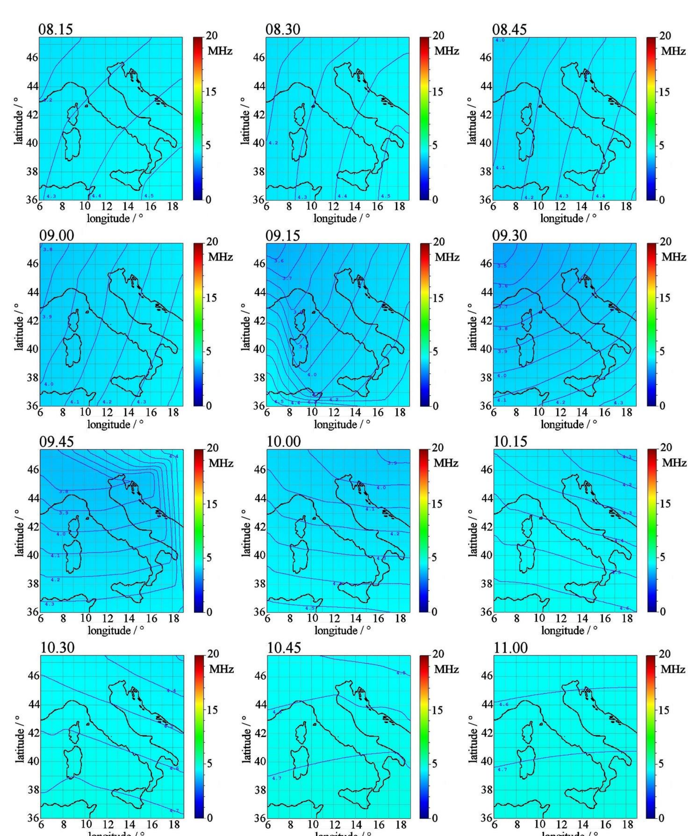

Fig. 3

In figure 3 are reported the maps of estimated f_oF_1 taken every 15 minutes over the Italian region, when the eclipse occurs. In Figure 4 we show time behaviour of the observed values f_oF2_{obs} in the three ionospheric stations of Rome, Gibilmanna and San Vito. f_oF2_{obs} is the measured f_oF_2 values deduced from the ionograms manual scaling. In the same figure is shown with black dots, f_oF2_{mod} which is a value representing the temporal evolution of f_oF2_{obs}, as it would be expected if the eclipse was not there. The f_oF2_{mod} 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 $d = f_oF2_{mod} - f_oF2_{obs}$ 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 f_oF_2 values applying the SOF correction, can be seen with f_oF2_{obs} .

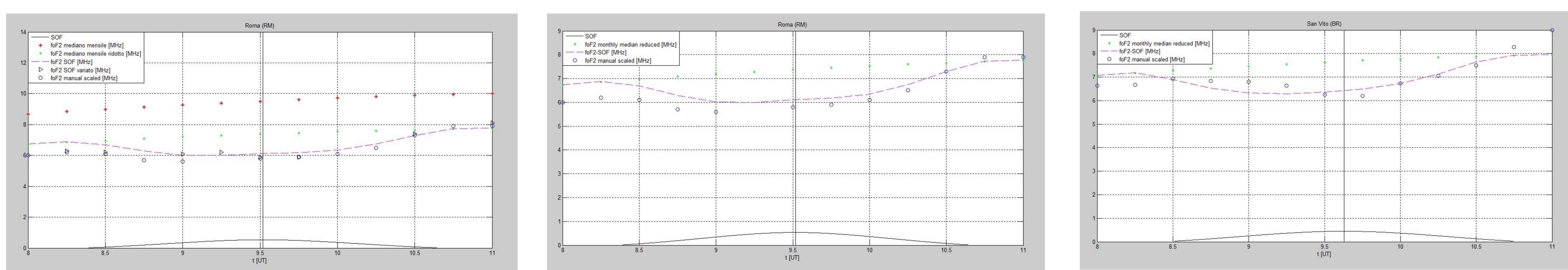

Fig. 6 (a) (b) (c)

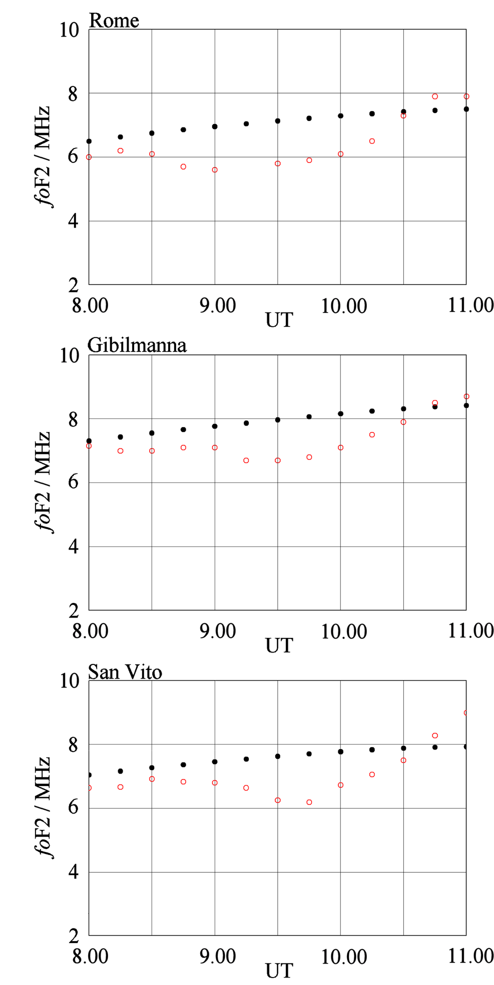

Fig. 4

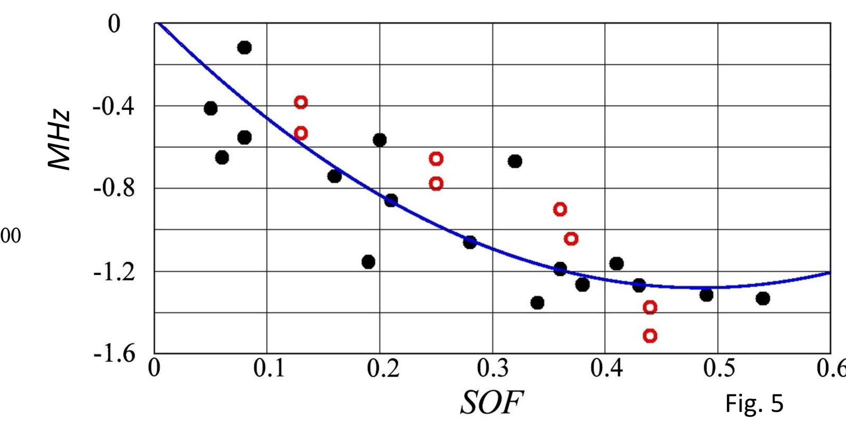

Fig. 5

The behaviour of a regional adaptive and assimilative 3D ionospheric model (Sabbagh et al., 2016) has been tested as well, when it assimilates plasma frequency profiles $f_p(h)$ during the solar eclipse. The performances of the model have been evaluated in terms of the adaptability to ionospheric conditions observed at a given moment over Rome and Gibilmanna. The accuracy with which the algorithm is able to model f_p has been tested over San Vito dei Normanni.

As applying the SOF corrections the estimated values of f_oF_1 and f_oF_2 present a close agreement with the observations, these corrections have been introduced in the model in order to let make it follow the eclipse effects. This capability is shown for example in figure 7 in which are reported the maps of f_oF_2 generated by the model every 15 minutes over the Italian region in correspondance of the eclispe occurrence. As can be seen, the isolines shown in this figure follow the shape of the SOF isolines showed in figure 1. A study on the occurrence of the Sporadic E layer during the solar eclipse is also presented, using data from Rome and Gibilmanna ionosondes.

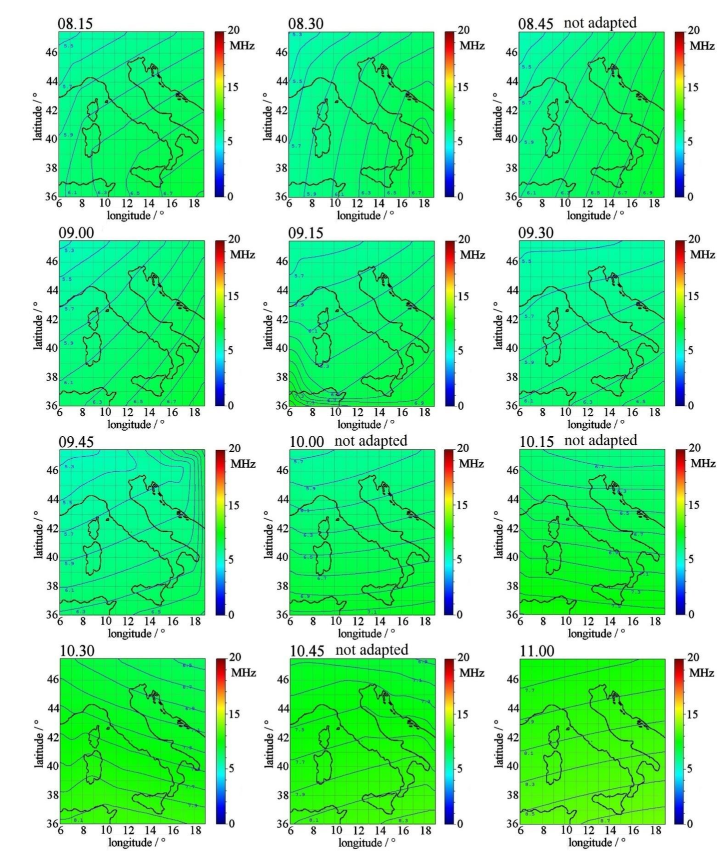

Fig. 7

In panels (a) of figures 8 and 9 we report the analysis of received eco 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.

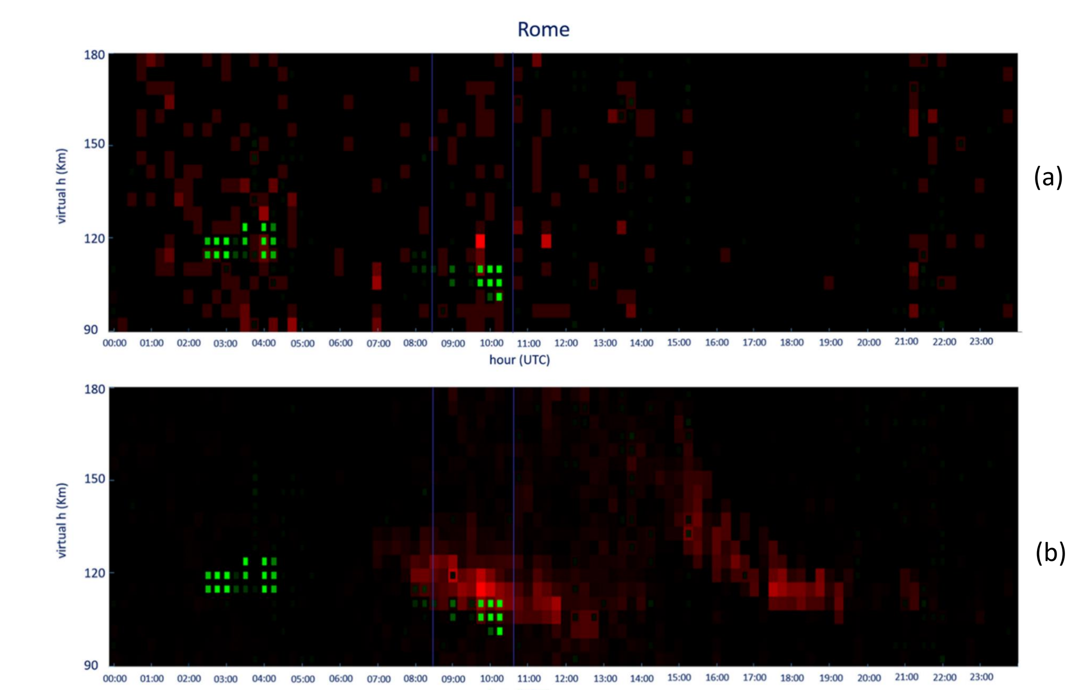

Fig. 8

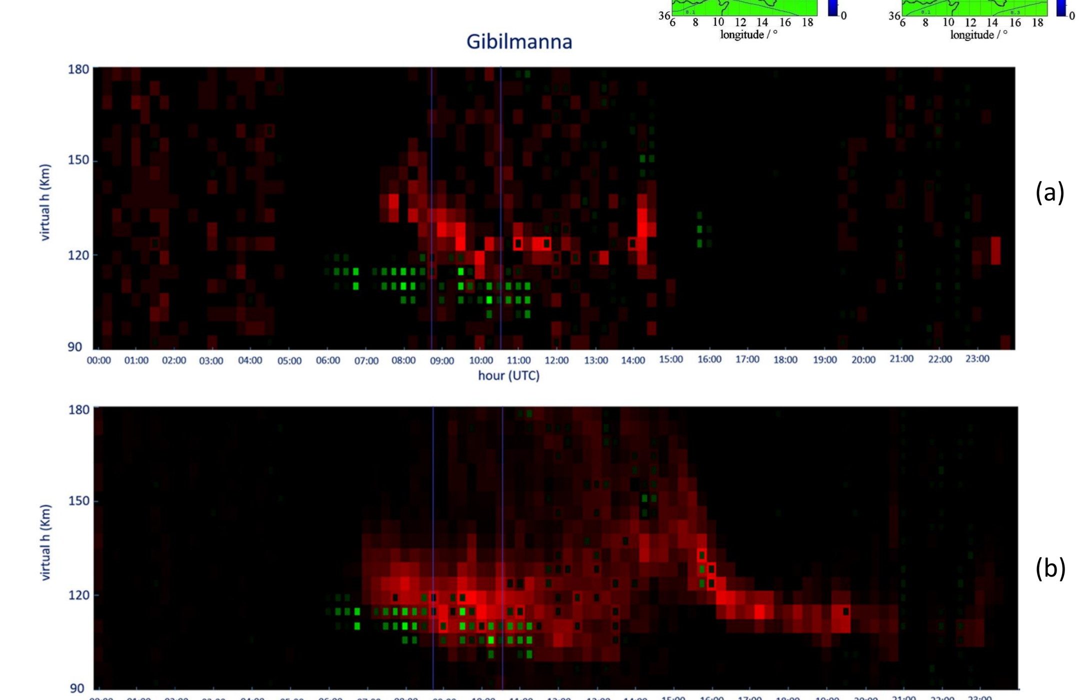

Fig. 9

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