Comparison of various methods to control conditions of radio wave propagation in the ionosphere

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Abstract

Conditions of radio wave propagation in the ionosphere can be described and controlled in various ways: 1) a model of the ionosphere, 2) critical frequencies from the vertical sounding data, 3) critical frequencies obtained using the values of the total electron content TEC, 4) maximum observed frequencies for a particular path, 5) values of plasma concentration, measured by satellite. Comparison of these data on real path using the IRI model, global maps of TEC, experimental data of CHAMP PLP shows that the conditions for the propagation of radio waves in the ionosphere can be controlled by an equivalent thickness of the ionosphere.

1. Introduction

Conditions of radio wave of propagation in the ionosphere can be described and controlled in various ways: 1) a model of the ionosphere, 2) critical frequencies from the vertical sounding data, 3) critical frequencies obtained using the values of the total electron content TEC, 4) maximum observed frequencies for a particular path, 5) values of plasma concentration, measured by satellite. The use of empirical models is the most accessible method, especially in the long term variant. They can be done closer to real conditions by parameter adaptation. Vertical sounding can provide critical frequencies and other parameters in real time, but it has certain disadvantages: a lack of a dense network of stations and data gaps. Parameter TEC is increasingly being used to characterize the state of the environment as it provides continuous monitoring, but also to determine the critical frequency foF2 is necessary to know the value of an equivalent thickness of the ionosphere τ. To determine τ must simultaneously have the values TEC and the plasma density NmF2 at the same point. Measurement of maximum observed frequencies MOF is the best way to determine the conditions, but experimental data are very sparse, and the available data contain many gaps. Gaps can be filled with the propagation coefficients MD for a particular path and frequency foF2. Concentration measurements from satellites can be used for self-correction models. In our case, the concentration measurements are involved to determine the equivalent thickness. In this study, all of these types of methods are compared to show that the equivalent thickness of the ionosphere can be used to control the propagation conditions.

2. Experimental data and the defined values

The results are illustrated by the example of the propagation characteristics along the path England - Moscow [1], so all the defined values refer to this area. The IRI model was selected as an empirical one [2]. Conditions apply to April 2002, for which the geophysical situation is presented in detail in [3]. It is important that they are characterized by two disturbances caused by increased By-component of IMF and a negative disturbance. Values of foF2 are selected from SPIDR database for the stations Chilton, Moscow (path terminals), Juliusruh. TEC values are taken from the global JPL maps. The value of τ is determined at these points and used to determine foF2 at the point of the middle of the path. The values of absolute deviations, mean square and relative deviations are used to compare experimental and calculated values of the parameters (foF2, M3000F2, MUF, etc.). MUF is determined using the propagation coefficient of MD(IRI), the correctness of which is confirmed by comparing experimental and calculated values of M3000F2 at selected points. Values τ calculated by the TEC are used to fill gaps of foF2 and MUF.

3. Results

To describe the conditions for using the model in April 2002, Fig. 1 shows the model values of foF2(IRI) and the experimental medians for endpoints of the path (Chilton and Moscow) together with absolute deviation $|\Delta foF2|$ between presented values. Fig. 2 shows the corresponding medians of M3000F2. Fig. 3 gives the medians of MOF and the equivalent thickness τ.

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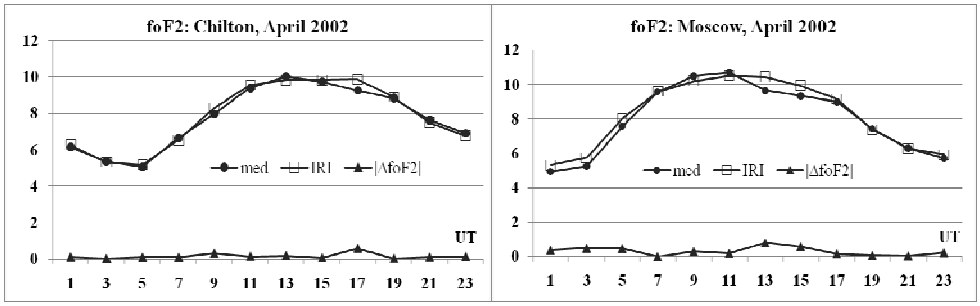

Figure 1. Comparison of experimental and calculated medians of foF2 in April 2002

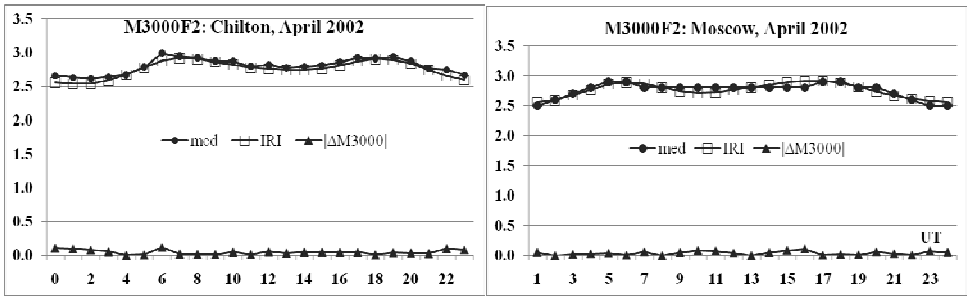

Figure 2. Comparison of experimental and calculated medians of M3000F2 in April 2002

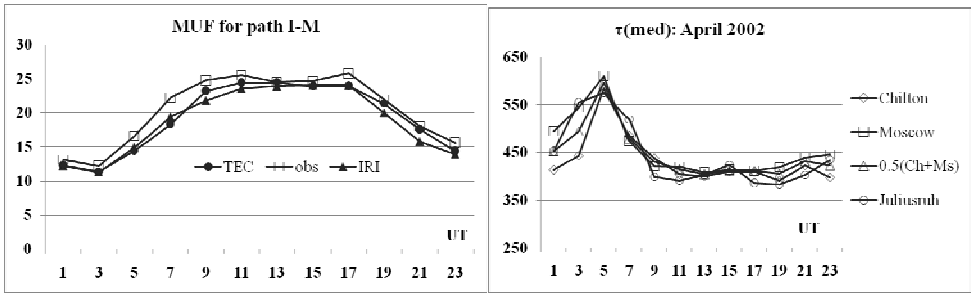

Figure 3. Comparison of experimental and calculated medians of MUF (left panel) and medians of τ (right panel) for various stations in April 2002

It is seen that the IRI model provides a good agreement with experimental medians in conditions of high activity and disturbed month. Fig. 4 illustrates how the model describes the state of the ionosphere in this case, if it is used for the situation of each day. The values of |Δ foF2| are shown for model (IRI), for using the median τ(med) and hyperbolic regression with τ(Nm).

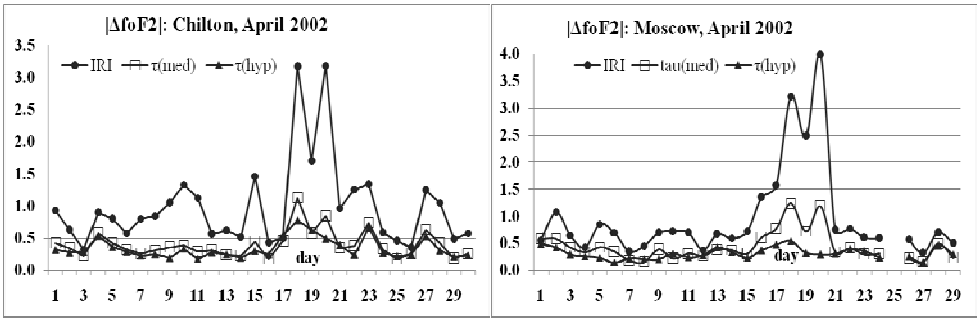

Figure 4. Illustration of effectiveness of using TEC before the IRI model

The average value of |ΔfoF2| for the median τ(med) is an estimate of the accuracy of filling gaps of foF2, if data are missing. Dependence τ(Nm) considers the behavior of τ during the disturbance and can be used to determine |ΔfoF2| in neighboring areas. In this month foF2 values were presented for virtually all of the stations and the values of MOF are often absent. Fig. 5 shows the results of the reconstruction of these values using the TEC in

the mid-point of the path and the median τ(med) for the station Juliusruh (Fig. 3). At the top of the figure are given the values of TEC, at the bottom - the MUF.

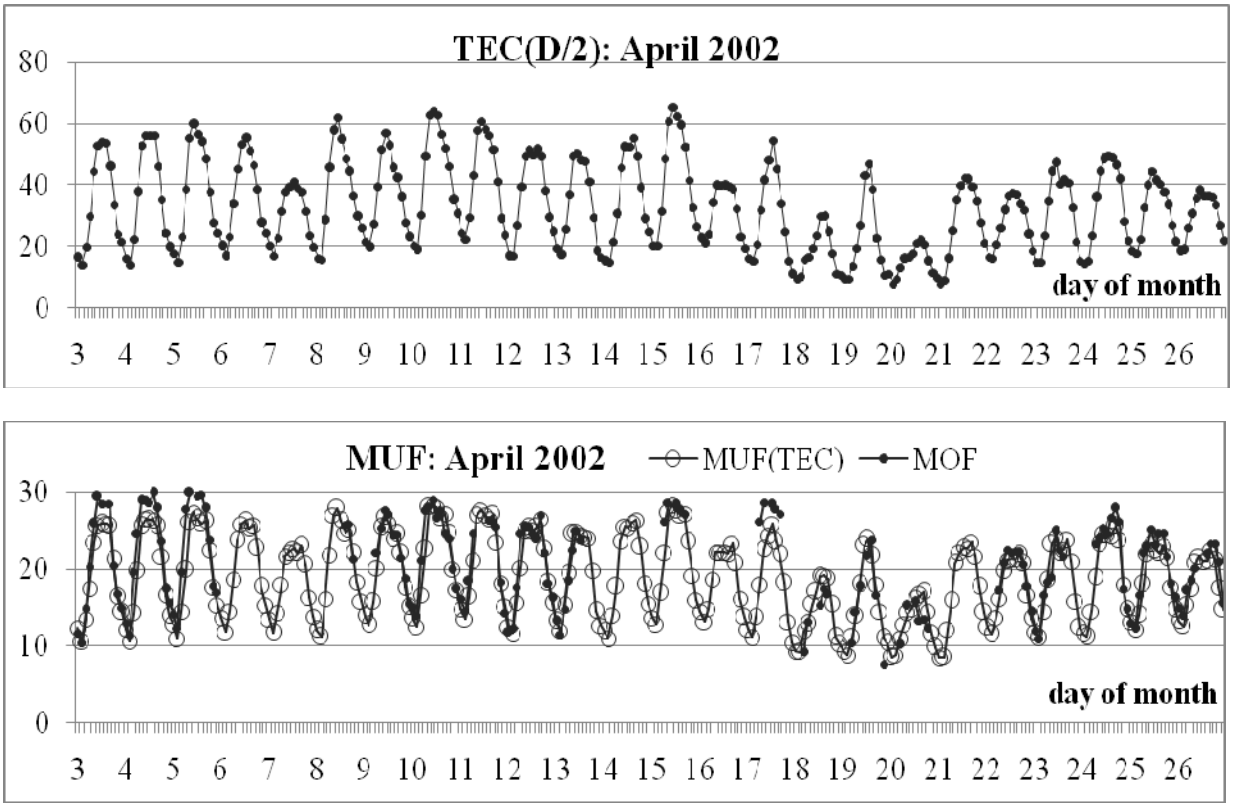

Figure 5. Example of MUF reconstruction by means of TEC in the mid-point of the path

It is evident that if there are experimental values of MOF, than recovered MUF correspond to them quite well. This allows to conclude that the values of the MUF in the gaps should be close to the real values. The experimental data of CHAMP PLP [4] allow to receive the monthly medians of foF2, and the use of TEC at a given point - to obtain the median τ(med) without reference to the data of vertical sounding. Fig. 6 shows the medians of foF2, obtained for the station Moscow from the model (icon IRI), according to VS (VS) and satellite (CH). Fig. 7 gives the medians CH for the mid-point of the path.

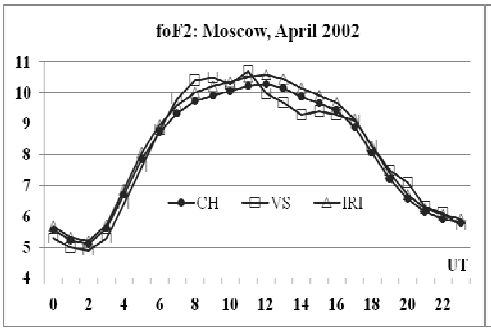

Figure 6. Comparison of various way of foF2 determination: CH, VS, IRI

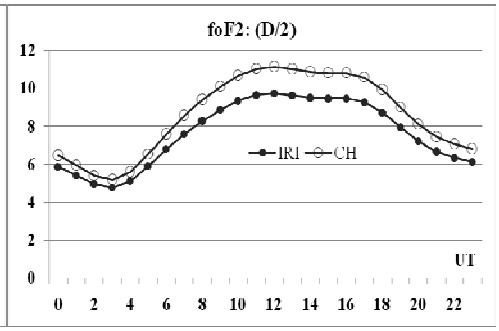

Figure 7. Comparison of foF2 calculated by the model IRI and experiment CH

Fig. 8 shows the values of τ(med), and Fig. 9 presents MUF values obtained using data from CHAMP.

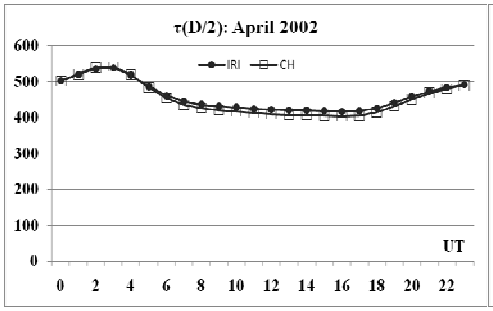

Figure 8. Comparison of τ(med) in the middle of the path

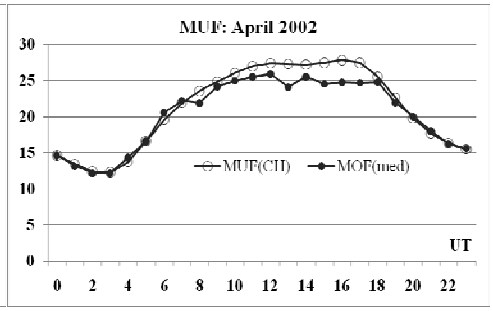

Figure 9. Comparison of experimental MOF and MUF obtained by TEC

It is seen that the equivalent thickness of the ionosphere can be used to determine the propagation conditions. Similar results were obtained for the Cyprus-Moscow path in April 2002.

4. Conclusion

Comparison of different data to describe and control the radio wave propagation conditions, among other results shows that the equivalent thickness of the ionosphere can be used for such control. The results are illustrated on data from past eras, but it is obvious that such an approach can be implemented in real time with appropriate data.

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6. References

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