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A single-station prediction model as a source of additional screen-points for PRIME model

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Abstract
The aim of this paper is to present a possible improvement to the global map of the f_0F_2 parameter obtained using statistical or any other model, by adding to it the additional screen points. The proposed method is illustrated by combining the CCIR model and a set of single points data. The comparison of the pure global CCIR model and CCIR model modified by the additional screen-points with measurements for different seasons and different solar activity is presented. The results show significant improvement of the f_0F_2 map.

Key words *ionosphere – ionospheric mapping – ionospheric modelling*

1. Introduction

The option of using the generated screen-point values for PRIME purposes was considered by Bradley (1992). The use of screen-point values for locations remote from those with available data, to improve grid maps were demonstrated by Samardjiev *et al.* (1993). This paper presents the possible combination of measurements or modelled values at particular points that can be randomly sparsed and the statistical or any other global model. The possible improvement of the global map of the f_0F_2 parameter is shown by introducing to it the additional screen points. The method is illustrated by combining CCIR (1992) model and a set of single points data. The general scheme of the procedure is presented in fig. 1.

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2. Method

The method used for calculation of the presented results is based upon the Rush and Edwards method (Rush and Edwards, 1976) with two modifications. One of the modifications described in Juchnikowski and Zbyszyński (1991) ensures that the fitting is exact. The following mathematical trick is used:

$$s_i = \frac{w_i + \varepsilon}{1 - w_i + \varepsilon}$$

$$w_i^* = w_i \cdot \frac{s_i}{\sum_{j=1}^{N} s_j}$$

$$f^* = f + \sum_{i=1}^{N} (g_i - f_i) \cdot w_i^*$$

where function $f(\phi, \lambda)$ represents the statistical global model of f_0F_2 depending on geographical coordinates and f^* is an improved modelled

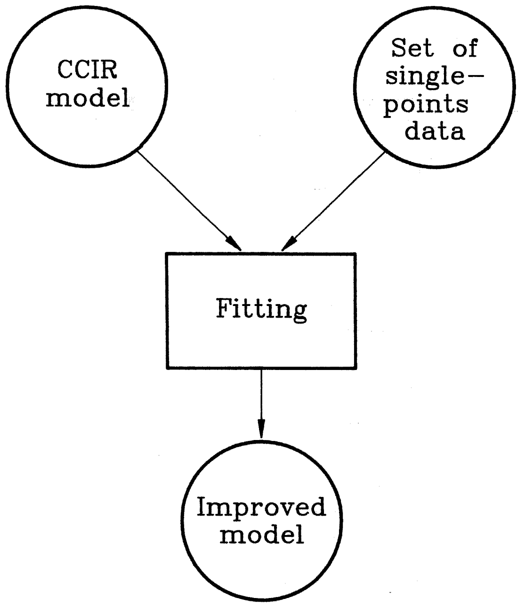

Fig. 1. General scheme of the procedure.

value. $g_i = g(\phi_i, \lambda_i)$ are values of f_0F_2 given at particular N points. Instead of measurements as g_i can also be taken values more accurate than global model different local models. These values affected the whole map of area of interest. A set of original weighting factors $w_i = w(\phi_i, \lambda_i, \phi, \lambda)$ that are factors of statistical dependence of f_0F_2 at points (ϕ, λ) and (ϕ_i, λ_i) is given. The weight $w_i = 1$ when $(\phi_i, \lambda_i) = (\phi, \lambda)$ and $0 \leq w_i < 1$ when points do not coincide. In simple cases w_i is a function of distance between the two points. w_i^* are modified weighting factors, ε – small number (*e.g.* 10^{-6}) eliminating some problems with infinity. Another modification of the method is caused by the fact that the autocorrelation of f_0F_2 is about twice as strong in longitudinal directions than in latitudinal (Gibson and Bradley, 1991). In terms of equations it is expressed in the following formulae for the original weighting factor:

$$w_i = \exp - \left[\left(\frac{dx}{R_\lambda} \right)^2 + \left(\frac{dy}{R_\Phi} \right)^2 \right]$$

where R_λ = 4000 km and R_ϕ = 2000 km.

3. Results

The analysis of influence of additional values to the global CCIR model was provided by comparison of results in some control points. The additional data were introduced in this case not by local models, but by real measurements made at stations within the PRIME area. The list of the stations is presented in table I. These data were obtained from the PRIME Data Bank in Lannion (Hanbaba, 1992). Control points were chosen from these stations, excluding them during calculations. Days for calculations were chosen according to rules having examples for low and high solar activity defined by 12-month smoothed sunspot number R_{12}, summer and winter time, and for disturbed and quiet ionospheric conditions. The chosen days and stations are presented in table II.

The results of the «pure» global CCIR model and CCIR model with fitting procedures are presented in four tables as statistical parameters of performed calculations. The statistical calculations presented at tables III to VI are:

– in the first column: standard deviations of the expression (model-measurement),

$$\text{Stand. dev.} = \sqrt{\frac{\sum(\text{mod.}-\text{meas.})^2 - \frac{(\sum(\text{mod.}-\text{meas.}))^2}{N}}{(N-1)}}$$

– in the second column: the average value of percentage deviation,

$$\text{Aver.} = \frac{1}{N}\sum \frac{\text{abs.}(\text{mod.}-\text{meas.})}{\text{meas.}} \cdot 100\%$$

– in the third column: scatter error,

$$\text{Scat.} = \sqrt{\frac{\sum(\text{mod.}-\text{meas.})^2}{N-1}}$$

Table I. List of stations ordered by geographic latitude.

No.	Station name	Geographic latitude	Geographic longitude	Dipole latitude	Dipole longitude
1	Uppsala	59.80	17.60	58.31	106.88
2	South Uist	57.37	352.67	60.89	81.24
3	Kaliningrad	54.70	20.62	52.86	106.43
4	Juliusruh	54.63	13.38	54.28	97.30
5	St. Peter Ord.	54.34	8.62	53.80	94.90
6	Slough	51.48	359.43	54.03	84.44
7	Kiev	50.50	30.50	47.14	113.34
8	Dourbes	50.10	4.60	51.70	88.88
9	Pruhonice	49.98	14.55	49.63	98.45
10	Lannion	48.75	356.55	51.99	80.14
11	Poitiers	46.57	0.35	49.17	83.01
12	Sofia	42.68	23.35	40.93	103.80
13	Rome	41.90	12.50	42.29	93.20
14	Lisbon	38.80	350.80	43.60	70.73
15	Gibilmanna	37.59	14.01	37.83	93.21

Table II. Description of the days taken into consideration and the station control points (R_{12}).

1986 August 14, 15, 21, 22, 28, 29, 30	Dourbes, Rome, Uppsala, Slough	(12.7)
1986 December 14, 22, 23, 24, 25, 28, 29	Dourbes, Rome, Uppsala, Slough	(16.1)
1989 May 17, 18, 19, 20, 23, 24, 25, 26	Dourbes, Rome, Uppsala, Lisbon	(156.1)
1989 December 9, 10, 11, 16, 22, 29, 30	Poitiers, Rome, Uppsala, Lisbon	(154.7)

– in the fourth column: systematic error,

$$\text{Syst. err.} = \frac{\sum(\text{mod.} - \text{meas.})}{N}.$$

Two values in each column represent «pure» CCIR and CCIR with fitting. In almost all cases a noticeable improvement is obtained after introducing the fitting procedure. However, when the control point is far from points of given f_0F_2 values the results are not as good as when the control point is situated closer. Also the comparison for the Uppsala station, especially during winter conditions shows a remarkably smaller improvement. The Uppsala station is the most northern situated station considered, and the f_0F_2 values measured so far at the north are mainly imposed by the position of the ionospheric trough. In such cases the additional values of f_0F_2 from the southern part of the map do not modify this specific area, as strongly as the trough.

The results of averaging the data presented in four tables are given in table VII.

A similar comparison of the improved model with the map obtaining using Kriging interpolation procedure (commercial package SURFER, Golden Software Inc.) is as follows:

Total (2536)	0.95	11.2%	0.96	−0.17

Table III. Results of comparison of the pure global CCIR model and CCIR model with fitting procedure for summer, minimum solar activity.

Stations	No.	Standard deviation		Average		Scatter		Systematic error	
		CCIR	With fitting	CCIR	With fitting	CCIR	With fitting	CCIR	With fitting
All stations	565	0.59	0.33	12.2%	6.0%	0.59	0.33	0.06	−0.02
Dourbes	161	0.55	0.19	11.1%	3.7%	0.55	0.19	−0.01	−0.02
Rome	159	0.67	0.44	12.3%	7.4%	0.69	0.45	0.14	−0.12
Slough	138	0.54	0.19	11.5%	3.8%	0.55	0.20	−0.10	−0.05
Uppsala	107	0.51	0.39	14.6%	10.1%	0.57	0.42	0.26	0.15

Table IV. Results of comparison of the pure global CCIR model and CCIR model with fitting procedure for winter, minimum solar activity.

Stations	No.	Standard deviation		Average		Scatter		Systematic error	
		CCIR	With fitting	CCIR	With fitting	CCIR	With fitting	CCIR	With fitting
All stations	571	0.82	0.50	17.8%	10.4%	0.82	0.50	0.02	0.01
Dourbes	167	0.70	0.31	15.9%	6.7%	0.70	0.31	−0.07	0.00
Rome	155	0.79	0.44	14.9%	8.0%	0.82	0.44	0.21	−0.03
Slough	145	0.86	0.35	17.0%	7.2%	0.77	0.36	−0.15	−0.09
Uppsala	104	1.02	0.83	26.4%	24.0%	1.03	0.86	0.14	0.22

Table V. Results of comparison of the pure global CCIR model and CCIR model with fitting procedure for summer, maximum solar activity.

Stations	No.	Standard deviation		Average		Scatter		Systematic error	
		CCIR	With fitting	CCIR	With fitting	CCIR	With fitting	CCIR	With fitting
All stations	740	1.14	0.63	13.3%	6.3%	1.15	0.67	0.16	−0.22
Dourbes	190	1.07	0.21	13.3%	2.7%	1.09	0.24	0.20	0.12
Rome	190	1.19	0.67	12.7%	7.0%	1.24	0.73	0.35	−0.29
Uppsala	187	1.23	0.50	17.1%	6.7%	1.23	0.50	0.12	−0.02
Lisbon	173	1.01	0.68	10.0%	9.0%	1.01	1.01	−0.04	−0.74

Table VI. Results of comparison of the pure global CCIR model and CCIR model with fitting procedure for winter, maximum solar activity.

Stations	No.	Standard deviation		Average		Scatter		Systematic error	
		CCIR	With fitting	CCIR	With fitting	CCIR	With fitting	CCIR	With fitting
All stations	660	1.71	1.19	23.4%	17.0%	1.72	1.20	−0.16	−0.16
Rome	167	1.39	0.88	16.7%	10.4%	1.39	0.88	0.08	−0.02
Uppsala	159	2.23	1.67	42.7%	36.4%	2.27	1.77	0.45	0.58
Lisbon	167	1.37	0.99	16.7%	15.4%	1.45	1.23	−0.47	−0.72
Poitiers	167	1.51	0.47	18.6%	6.9%	1.66	0.63	−0.68	−0.43

Table VII. Results of comparison of the pure global CCIR model and CCIR model with fitting procedure.

Stations	No.	Standard deviation		Average		Scatter		Systematic error	
		CCIR	With fitting	CCIR	With fitting	CCIR	With fitting	CCIR	With fitting
Total	2536	1.17	0.76	16.7%	9.9%	1.17	0.76	0.02	−0.11

4. Conclusions

It is shown that the CCIR map modified with single-points data is noticeably better than the pure CCIR map. It is also shown that such a combined result (modified CCIR map) is significantly better than the map obtained from measurements only. It is expected that all single-station prediction or forecasting models within the PRIME area can be used as single-point data to improve the global model.

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