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Real-time ionospheric N(h) profile updating over Europe using IRI-2000 model

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Abstract. In this paper a method for real-time updating of ionospheric electron density profile, N(h), over Europe using an ionospheric model and real-time measurements at ionosonde locations is presented. The N(h) profile update over European area has been simulated with the IRI-2000 ionospheric model and real-time N(h) profiles obtained from the EU COST271 Action Space Weather Database. Preliminary findings are shown for the geomagnetically quiet day on 4 May 2003 and disturbed day on 24 May 2002. Results are discussed in the context of real-time N(h) profile updating capabilities and effectiveness.

1 Introduction

The International Reference Ionosphere-IRI (Bilitza, 2001) is one of the most widely used empirical models. Among others, it describes the median values of electron density as a function of height for a given location, time and sunspot number. The IRI model is being refined following the annual IRI workshops and currently contains the foF2 storm model (Araujo-Pradere, et al., 2002a, b; Bilitza, 2003). This paper presents the comparative study of the electron density maps generated using a method for real-time ionospheric N(h) profiles updating and those obtained by the IRI-2000 model over Europe. The intent is to provide a possibility for a further IRI model improvement. Therefore, in this study the N(h) profile simulation has been performed by using online information available at the IRI web side http://nssdc.gsfc.nasa.gov/space/model/models/iri.html and at the COST271 Space Weather Database web side http://www.wdc.rl.ac.uk/cgi-bin/digisondes/cost_database.pl. (Zolesi and Cander, 2003). A few other stations operating in non real-time mode in Europe are used to provide additional IRI-2000 N(h) profiles required for mapping NmF2, hmF2 and electron density at the F1-region heights over Europe. Ionospheric stations involved in this study are listed in Table 1.

Initial comparison of the measured and IRI generated N(h) profiles has been done for two stations: Pruhonice and Ebre. Some of the results obtained for the period of 14–21 February 1998 are given in Fig. 1. In this period the first three days were geomagnetically quiet, followed by the storm on 18 February and then a long lasting recovery phase. At Pruhonice station it can be seen that: (1) there is a good agreement between IRI model (red line) and NmF2 measured data (black line) for the whole period; (2) in general, there is no agreement between IRI model and electron density measured values at F1-region height. It is particularly true during the main phase of the geomagnetic storm and at the height of 180–190 km in the F1-region. The same is valid for the similar comparison made for Ebre station also shown in Fig. 1.

Examples at Fig. 1 demonstrate that it is possible to use IRI model for mapping ionospheric electron density at the certain heights over European region, as at hmF2 and at fixed F1-region heights, during quiet ionospheric conditions. During disturbed conditions IRI still cannot produce appropriate values mainly at F1 heights and therefore reasonably accurate N(h) profile as a whole. This is the main reason to introduce a method of the ionospheric 3D modelling by real-time N(h) profile updating with measured data.

2 Real-time N(h) updating results

Figure 2 shows the 4 May 2003 geomagnetically quiet study case at 11:00 UT. Left panel contains maps of electron density measured data at hmF2 and 190 km, while on the right panel maps are produced by IRI model using the same locations of five stations. It can be seen that NmF2 map over Europe obtained by measured values from selected stations was slightly different than IRI map itself. In the case of F1-region electron density maps it is clearly evident the significant discrepancy between maps of measured electron density data and IRI map. The IRI model underestimated electron

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Table 1. List of contributing vertical incidence ionospheric stations.

VI station	Latitude (° N)	Longitude (° E)	Data available
Chilton	51.5	−1.3	Real-time mode
Athens	38.0	23.6	Real-time mode
El Arenosillo	37.1	−6.8	Non real-time mode
Ebre	40.8	0.5	Non real-time mode
Tromsø	69.9	19.0	Real-time mode
Roma	41.9	12.5	Real-time mode
Juliusruh	54.6	13.4	Real-time mode
Pruhonice	50.0	14.6	Non real-time mode
Warsaw	52.2	21.2	Non real-time mode
Dourbes	51.2	0.46	Non real-time mode
Uppsala	59.8	17.6	Non real-time mode

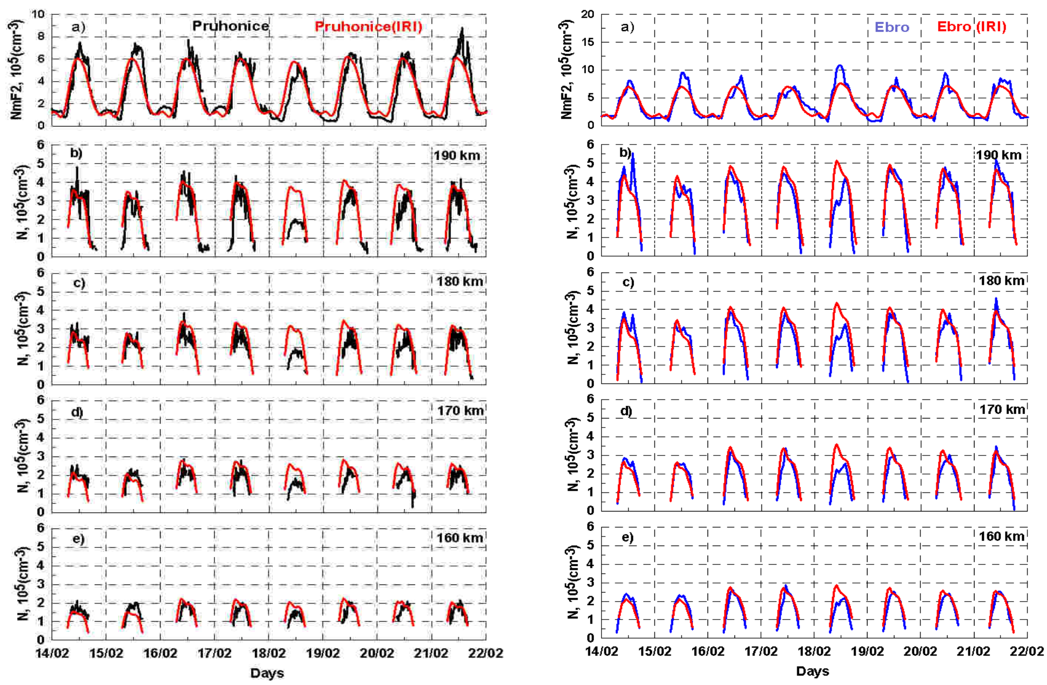

Fig. 1. Daily hourly NmF2 values and electron density values at specific heights obtained at Pruhonice (left panel) and at Ebre (right panel) stations and by IRI model during the period 14–21 February 1998.

density at 190 km height for all selected stations. To compare quiet and disturb periods in the same way as before, the disturbed day of 24 May 2002 was chosen based on the minimum value of the Dst index of −108 nT at late evening of the previous day. Figure 3 shows that at 11:00 UT on 24 May 2002 both NmF2 and the F1-region height maps over Europe obtained by measured values are significantly different than corresponding IRI maps. The advantage of using real-time data to update the IRI model values is obvious and most clearly seen at the F1-region height.

For the same days of 4 May 2003 and 24 May 2002 the simulation of an updating ionospheric model has been done by using 5 and 4 stations respectively, which offer the real-time measurements and the IRI N(h) profile values for other stations given in Table 1. Figures 4 and 5 show on the left side the simulated maps and on the right side maps produced with IRI values only for both selected days. Updated NmF2 maps and IRI model itself show relatively good agreement. In contrast to NmF2, updated F1-region maps differ significantly from maps generated using IRI model data. In general, at European middle latitudes the F1-region response to spring-summer time geomagnetic storm is significantly smaller compared to other seasons (Buresova, et al., 2002; Mikhailov and Schlegel, 2003). Consequently, the updated IRI model maps for F1-region are quite similar for both selected quiet and disturbed days. The most important result seen at the Figs. 4 and 5 is that updating IRI model describes the actual ionospheric structure better then the IRI model itself. The quality of the maps will obviously depend on the number of ionospheric stations which can provide the real-time N(h) profiles.

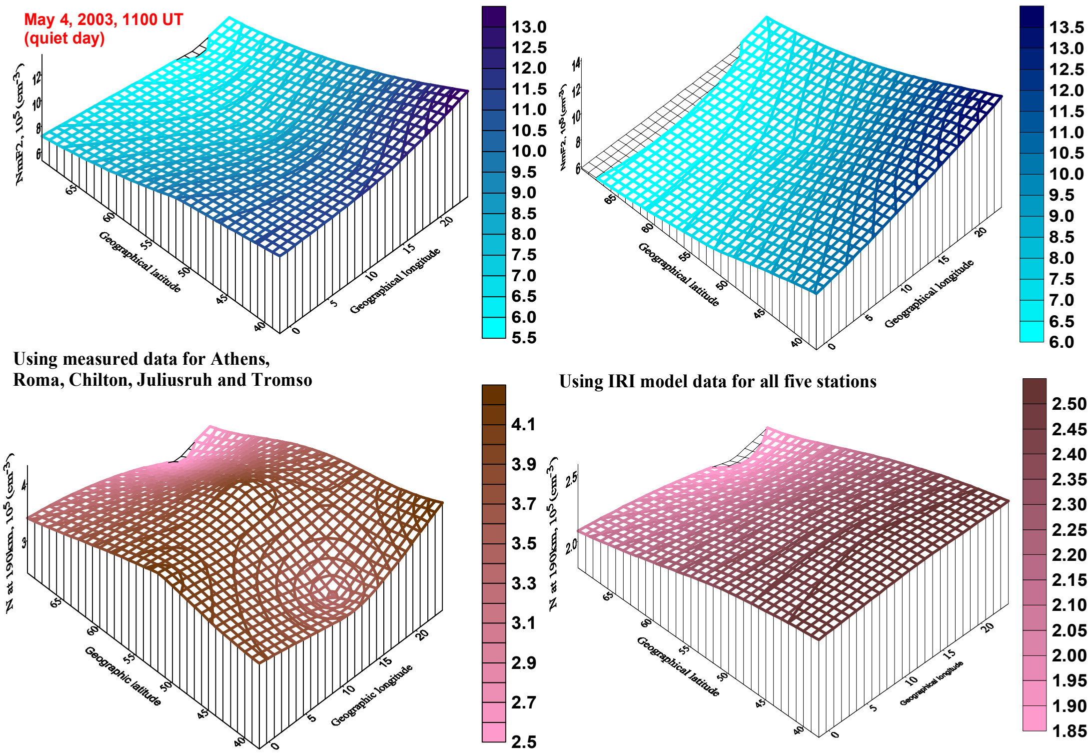

Fig. 2. Maps of the NmF2 and the electron density at 190 km values generated by measured data (left panel) and IRI data (right panel) on 4 May 2003 at 11:00 UT.

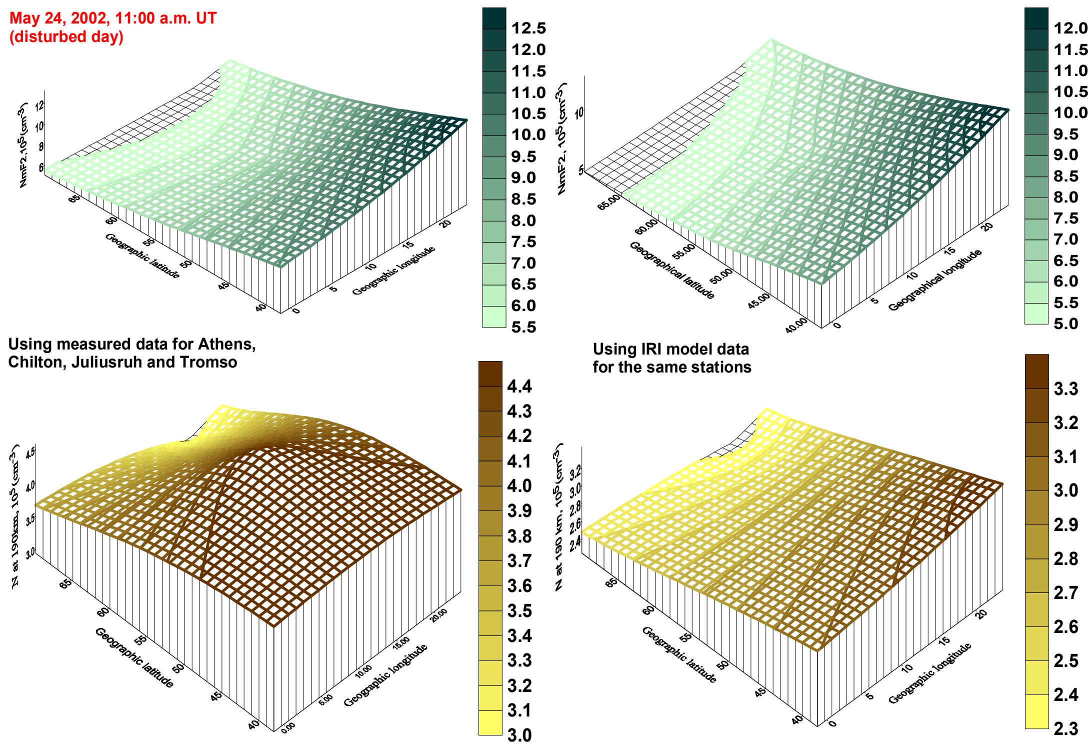

Fig. 3. Maps of the NmF2 and the electron density at 190 km values generated by measured data (left panel) and IRI data (right panel) on 24 May 2002 at 11:00 UT.

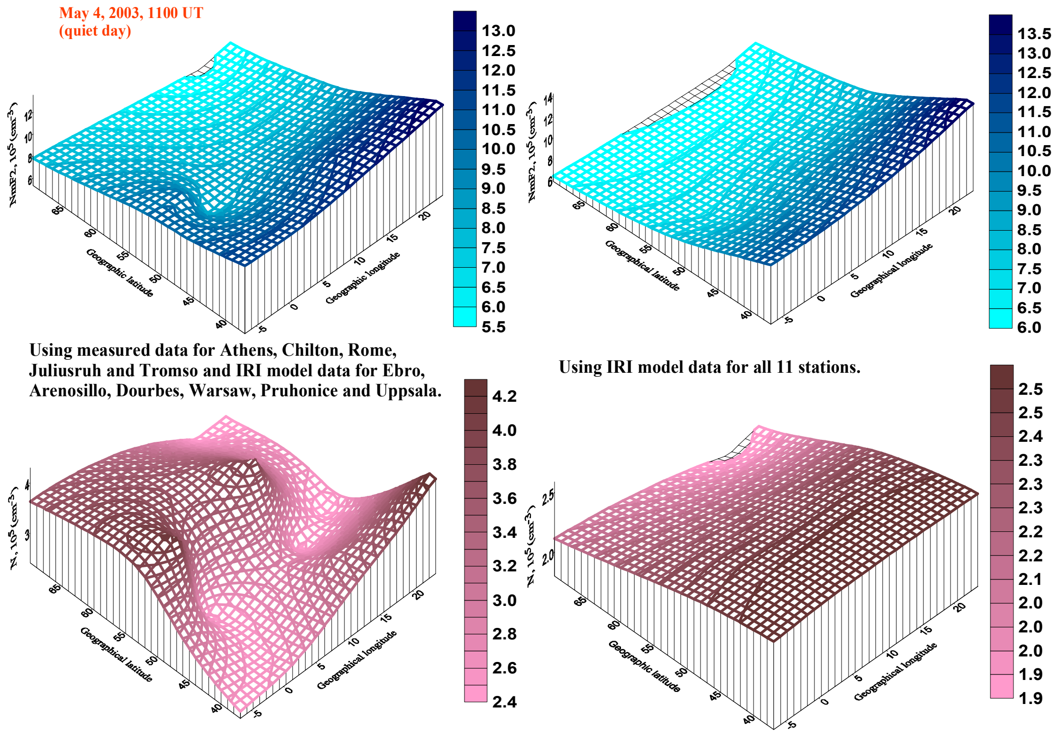

Fig. 4. Maps of the NmF2 and the electron density at 190 km values generated by measured data (left panel) for Athens, Roma, Chilton, Juliusruh and Tromsø and IRI data for Ebre, Arenosillo, Dourbes, Pruhonice, Warsaw and Uppsala on 4 May 2003 at 11:00 UT. Right panel represents the same ionospheric parameters calculated by IRI model for all selected stations.

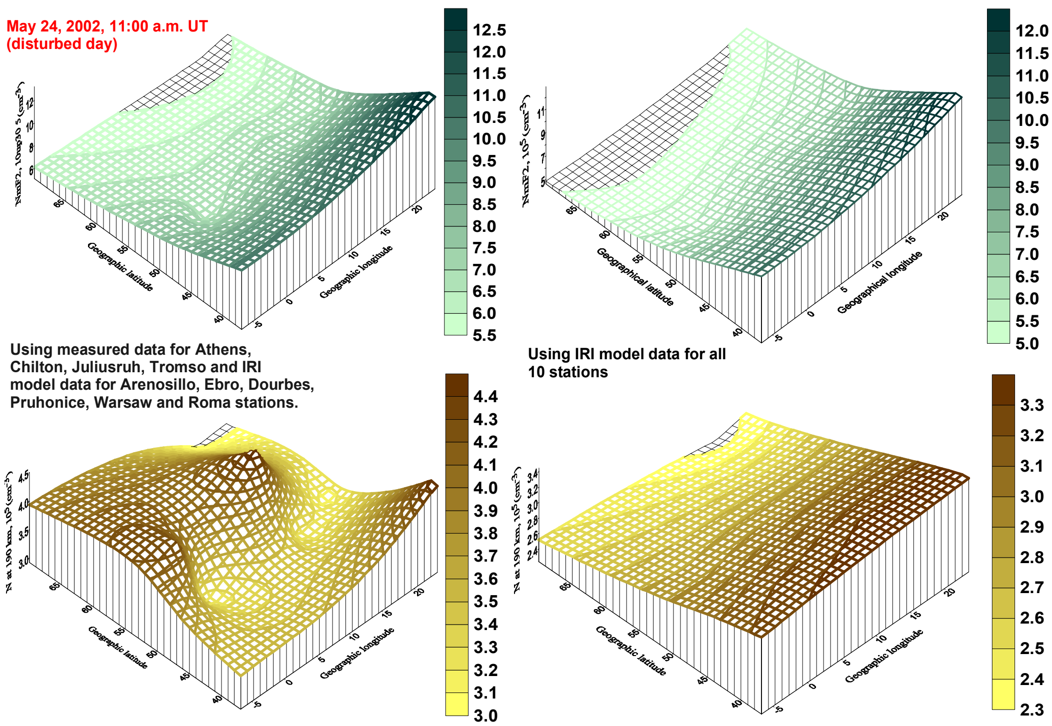

Fig. 5. Maps of the NmF2 and the electron density at 190 km values generated by measured data (left panel) for Athens, Chilton, Juliusruh and Tromso and IRI data for Ebre, Arenosillo, Dourbes, Pruhonice, Warsaw and Uppsala on 24 May 2002 at 11:00 UT. Right panel represents the same ionospheric parameters calculated by IRI model for all selected stations.

3 Conclusions

It is widely accepted that the IRI model needs improvement for better representation of the F1-region electron density distribution over Europe under the both geomagnetically quiet and disturbed conditions. Some of the results of our comparative analysis presented in this paper show that updated IRI-2000 model with real-time ionosonde data over Europe describes the actual ionospheric structure better than the IRI model itself. It is particularly valid during geomagnetically disturbed periods. The quality of the updated maps, which makes resulting N(h) profile more realistic, will however depend on the number of ionospheric stations that can provide the real-time N(h) profiles (Zolesi et al., 2004).

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