COORDINATED SRC AND RAL CENTERS FOR IONOSPHERIC WEATHER SPECIFICATION AND FORECASTING

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ABSTRACT

Radio wave propagation in the upper atmosphere is a complex phenomenon and manifests itself differently for different types of systems (e.g. fading level in a low-margin terrestrial communications system and excess time delay in a satellite navigation system for determining the range and location). Accurate propagation information is essential to support the design, implementation and operation of most modern terrestrial and satellite communication systems taking into account that communications through the upper atmosphere should meet more and more requirements. Here current co-ordinated Space Research Center and RAL activities on ionospheric weather specification and forecasting are presented.

1. INTRODUCTION

COST (Cooperation in Scientific and Technological Research) is an initiative of the European Union bringing together scientists to work on common research problems. COST 251 project - IITS (Improved Quality of Ionospheric Telecommunication Systems Planning and Operation) is a four-year project starting in April 1995 (Ref. 1). The aim of this project is to demonstrate the practical improvement to terrestrial and Earth-space radio systems of COST 238 - PRIME (Prediction and Retrospective Ionospheric Modelling over Europe) derived ionospheric models (Ref. 2) and to promote their use, to further refine these models and to widen their geographical area of applicability between latitudes of 35-70^o N and longitudes 10^o W-60^o E, and to collect additional quantities and types of ionospheric information and to extend the models to give system performance statistics (Ref. 3). The work has involved many extensive studies of the use of different solar, ionospheric and mapping indices for the prediction and forecast of the various ionospheric characteristics.

In the frame of the European COST 251 project operates co-ordinated Centres for ionospheric weather specification and forecasting. Since January 1997 in Heliogeophysical Prediction Service of the Space Research Centre of Polish Academy of Sciences (Regional Warning Centre Warsaw of the International Space Environment Service - ISES) has been located the COST 251 Ionospheric Despatch Centre for the Europe (IDCE) (Ref. 4). Under the National Radio Propagation Program, supported by the Radiocommunications Agency of the DTI, Radio Communications Research Unit (RCRU) at Rutherford Appleton Laboratory (RAL) provides ionospheric forecasts (Ref. 5). Both Centers offer to the international community data and prediction tools support in different studies and applications concerned with the space weather impact on radiocommunication. Details of these activities are given in Sections 2 and 3.

New COST project currently in preparation on Effects of the Upper Atmosphere on Terrestrial and Earth-space Communications has one among other objectives to study the impact of variability of space environment on communications with emphasised on: (i) Space weather data base with past and new measurements, as a service to space industries and others; (ii) Three dimensional electron density distribution and its time variability over Europe including other parameters in real-time modes; and (iii) Development of space weather now-casting and forecasting procedures and software tools in the domain. These future activities are presented in Section 4.

2. SRC CENTER

IDCE provides solar-geophysical data for COST 251 participants, particularly the ionospheric data from the European ionosonde stations. Some of data are available world wide. Data and special messages are accessible on ftp address: **cbk.waw.pl** and on IDCE home page **http://www.cbk.waw.pl/rwc/idce.html.**

Messages are prepared on the base of the local measurements, daily messages from RWC's: Boulder, Meudon, Moscow, Praha, Sydney, Tokio, Beijing and special messages obtained directly from stations: El Arenosillo, Juliusruh, Lannion, Lunping, Ondrejov, Sofia, Tortosa, Uppsala, Chilton. Data and global review of space weather (e.g. solar-geophysical situation) are available from the last few days and forecast for some days in advance. Daily message describes the solar, magnetic and ionospheric activities, sudden ionospheric disturbances, gives solar-geophysical situation review and forecast. Some ionospheric parameters are collected for the whole current and preceding month -hourly vertical-incidence ionosonde data. The map showing COST 251 area of Europe and indicating the locations of VI ionosondes available in the IDCE is presented in Figure 1. The data base is currently enriched with data from other ionospheric stations. IDCE provides also the catalogues of ionospherically disturbed and quiet days. On the base of the results of COST 238 project (Ref. 6), a list of the 5 disturbed and 5 quiet days of each month since January 1997 is produced. According to the criteria in Ref. 7 a catalogue of appreciable disturbances for duration of 3 hours or longer at several European ionospheric stations for 1998 is prepared.

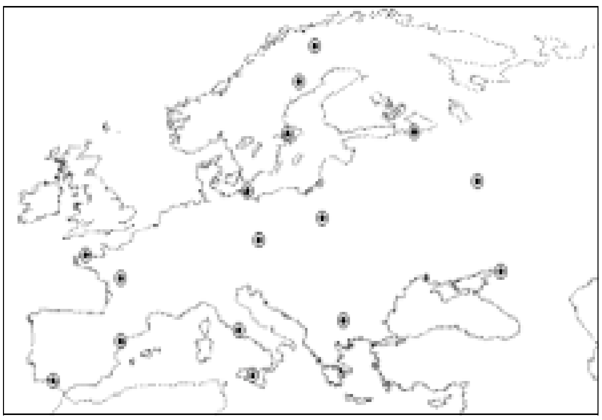
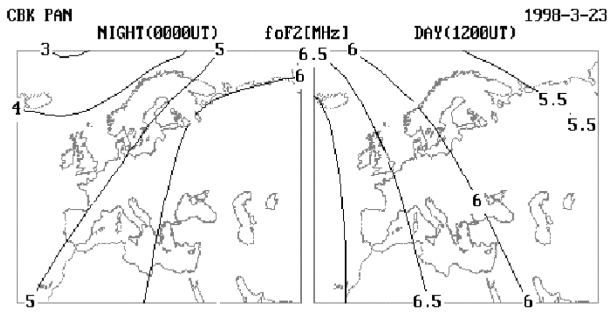


Figure 1. *Map showing COST 251 area. Circles indicate the locations of 15 from 31 vertical-incidence ionosondes contributing to IDCE. Black circles indicate the stations for which the catalogue of disturbances is providing*

On the base of the most recent measured data a graphical presentation of the instantaneous maps of foF2 parameter for Europe for 12 UT and 0 UT is available each day on www. Instantaneous mapping is defined as the technique that is applied when simultaneously measured or forecast values of ionospheric characteristics at limited numbers of locations are used for map generation appropriate to a single moment of time. The modified Kriging mapping technique has been used for gridding the foF2 measurements (Ref. 8). An example for the 23-th of March 1997 is shown in Figure 2. As the accuracy of the ionospheric map depends on its ability to describe the different phenomena, it should be noted that the prediction and forecast maps currently presented in most international propagation assessments ignore specific ionospheric phenomena. COST 251 studied some of these phenomena and the useful description of the morphological and dynamical identity of the ionospheric trough is given in Refs 9-11.

Figure2. *Sample instantaneous maps of foF2 for 23 March 1998*



3. RCRU/RAL CENTER

Telecommunication oriented project put the stress into studies of the ionospheric structures and their longitudinal and latitudinal variations in space, as well as diurnal, seasonal and solar cycle variations in time. It is clear that many propagation phenomena are critically dependent on the ionospheric variability. Availability of the instantaneous maps of ionospheric parameters as foF2 or M(3000)F2 and their forecast have the particular importance to HF propagation assessments and to Earth-space communication.

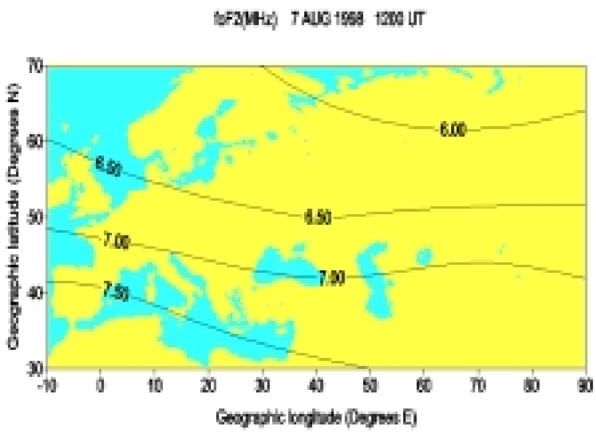


Figure 3. *foF2 map derived from forecast values for 24-hours ahead*

At RAL the real time ionospheric maps are generated at 1-hour interval to show the spatial extent and temporal development of ionospheric changes over Europe. The selected European geographical area lies between latitudes 35^0-70^0N and longitudes 10^0W-90^0E. The maps provides contours of foF2, the critical frequency of the F2 layer and MUF(3000)F2, the Maximum Usable

Frequency corresponding to 3000 km distance based on daily update from 23 ionospheric sounders.

Kriging interpolation procedure which, is suitable for this type of sparse data, is used to provide grid values from the original measurements. The grid resolution is 2.5 degrees in latitude and 5 degrees in longitude. Maps are provided for a given day and hour when at least 5 separate measurements are available for that time. By combining the Kriging spatial interpolation procedure with auto-correlation method for interpolation of foF2 time series, forecasts 24 hour ahead are obtained (Figures 3 and 4). The auto-correlation procedure has been developed by the Geophysical Institute, Bulgarian Academy of Sciences (Ref. 12).

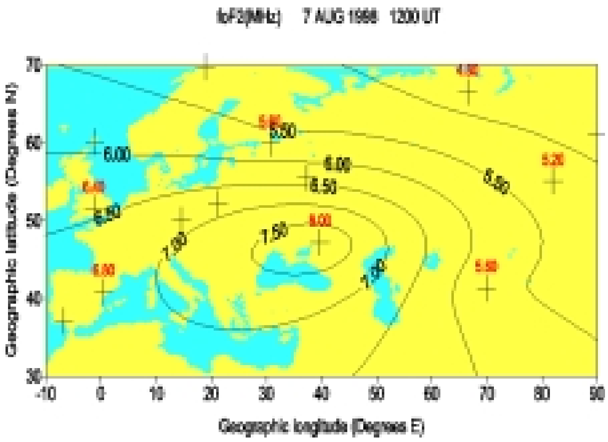


Figure 4. *foF2 map derived from measured values*

The web address for on-line ionospheric forecasts is as follows: **http://www:rcru.rl.ac.uk/iono/maps.htm.** This on-line RAL ionospheric forecast has become the official COST 251 project short-term forecasting tool since the last Management Committee meeting in October 1998.

4. FUTURE ACTIVITIES: IMPACT OF IONO-SPHERIC WEATHER ON COMMUNICATIONS

The COST 251 achievements are going to be implemented very soon in the computer programs prepared to provide predictions in accordance with the COST 251 recommended procedures. The operational use of such programs might need a number of solar-terrestrial indices as well as parameters as an input. Some of them are worldwide available, but for updating the ionospheric models also additional parameters can be required. These are currently available at IDCE. An example of such index is ionospheric monthly index MF2. IDCE offers MF2 indices since 1945 up to 1997 year, as well as their prediction up to 2005. SRC and RCRU/RAL Centers can offer main solar/magnetic/ionospheric indices needed for running the program (Ref. 13), as well as an access to the results of the program.

Ionospheric and plasmaspheric weather and its impact on terrestrial and space communications have drawn increasing attention in recent years. Therefore, the following-on COST project will focus on now-casting and forecasting models to be constructed and software tools to be developed, especially for GNSS. A three dimensional electron density distribution over Europe for on-line interactive use will be produced. Furthermore, particular attention will be paid to examine special properties of the high latitude ionosphere affecting communications. Monitoring of the upper atmosphere will be conducted on the basis of now-casting and forecasting procedures. The dynamical trough modelling will be addressed by further analysis.

Additional and new ionospheric and plasmaspheric data will be collected for now-casting and forecasting purposes. The new COST action will supply the framework to set up a network of European stations providing hourly updates of ionospheric and plasmaspheric measurements and other solar-terrestrial parameters relevant to space weather. GPS/GLONASS radio occultation measurements on board Low Earth Orbiting satellites (LEO's) provide a new tool for global sounding the Earth's ionosphere/plasmasphere systems. Combining ground based GPS measurements of vertical total electron content with the limb sounding data, tomographic solutions will provide the three-dimensional structure of the ionospheric electron density distribution. The effects of transient solar events like eclipses on communications will be measured and analysed. These activities will be coordinated jointly by SRC and RCRU/RAL Centers.

5. ACKNOWELEDGEMENT

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