

The European Server for Ionospheric specification and forecasting: Final results from DIAS project

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Abstract

The main objective of DIAS (European **D**igital **U**pper **A**tmosphere **S**erver) project is to develop a pan-European digital data collection on the state of ionospheric part of the upper atmosphere, based on real-time information and historical data collections provided by most operating ionospheric stations in Europe (Athens, Rome, Ebre, Juliusruh, Chilton, Pruhonice, Lycksele and Warsaw). Based on the raw data collection, DIAS system develops and distributes several products required by various groups of users for nowcasting and forecasting purposes. The DIAS server (<http://www.iono.noa.gr/DIAS>) operates since May 2005 and the basic products that are delivered are real-time and historical ionograms from all DIAS ionospheric stations, frequency plots and maps of the ionosphere over Europe based on the foF2, M(3000)F2, MUF and electron density parameters, as well as long term and short term forecasting up to 24 hour ahead. The paper reports on the operation of this new system, giving information on the models applied for the specification and forecasting of the ionosphere over the European region, and on the users' experience.

Introduction

The demand for reliable products that characterize the state of the ionosphere with high accuracy is nowadays very pressing, not only due to the specific needs of the European space industry (EGNOS and GALILEO) but also due to many applications operated by several market sectors. Radio frequency communications and satellite navigation and positioning systems can be adversely affected by disturbances caused directly by solar events and indirectly by effects in the near Earth environment. In particular HF sky-wave users, and also satellite communications (SATCOMS) operators can be affected by solar-induced, ionospheric disturbances. Depending upon the severity of the disturbances, the effects can cause significant degradation of the communications circuits and in the most extreme cases total outage of the systems causing potentially costly commercial and economic consequences. For military and civil defence communication applications for which HF is used, the ability to respond rapidly to dynamically changing external

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environmental effects is a key factor in enabling support for security, protection and control.

DIAS system [Ref. 1] has as primary objective to cover the needs of the market for reliable information on the current conditions of the ionosphere over Europe and for accurate forecasting information in long term and short term time scales. Europe has the advantage, in contrast to other world areas, to have in operation many ionospheric stations with a satisfactory geographic distribution. Nevertheless, even until recently, these stations operated independently, making the full exploitation of the ionospheric observations a very difficult task. DIAS managed for the first time to create a network among most of the European ionospheric stations, which is designed to serve radio propagation systems.

The paper reports on the operation of this new system, giving information on the models applied for the specification and forecasting of the ionosphere over the European region, and on the users' experience.

Tools for ionospheric specification and prediction

The development of the DIAS system has two fundamental components, the building of the DIAS server and the design and development of the added-value products and services.

The DIAS server development was based on a three layers' architecture. Layer 1 is the digital ionosondes data layer and consists of the soundings collected at all the participating stations in the DIAS network. To support DIAS, an information collector is installed at each station which uploads the ionograms and associated data to the central DIAS server. Layer 2 is the central DIAS server. In this layer all the ionospheric data is converted into a common format and stored in a database. Within layer 2 functionality exists which generates the numerous added-value products and services. These products are then made available as services via the World Wide Web (WWW). Layer 3 is the user layer and is the interface to the services and information products. The intention is that as well as provision of http, html and xml pages, ionospheric alerts will be sent to users via email or other text means.

The design and development of the added-value products was based on a comprehensive set of ionospheric models. These are used in conjunction with the ionospheric data sets derived from the contributing ionosondes.

The main models used in generating the products are:

1. The Simplified Ionospheric Regional Model (SIRM) used to provide long term forecasting maps of the foF2 & M(3000)F2 parameters. A full description of the model is given in Ref. [2].
2. The Simplified Ionospheric Regional Model Updated in real-time (SIRMUP) which uses real-time ionospheric sounder parameters (foF2 & M(3000)F2) to provide immediately updated nowcast maps. The method is described in Ref [3].
3. Ne3D which is a three dimensional instantaneous model of the ionospheric electron density used to calculate the distribution of the electron density with height over Europe and the method is described in Ref [4].

4. The Geomagnetically Correlated Auto-regression Model (GCAM) which provides nowcasts, short-term forecasts of foF2 for up to 24 hours ahead. The method is described in Ref [5].
5. The Time Series forecasting models for Absolute and Relative foF2 (TSAR-foF2) which provides forecasts of the foF2 parameter for up to 24 hours ahead, Ref [6].
6. Extensions to the SIRM and SIRMUP models to produce grided sets of the basic Maximum Usable Frequencies (MUFs), using the methods described in Ref [7].
7. The ionospheric Activity Index (AI) which is used to give a measure of the disturbed behaviour of the current ionospheric state, using the methods described in Ref [8]. The AI is a direct measure of the ionospheric activity.
8. The effective Sunspot Number is a parameter based on the predicted sunspot number used in conjunction with the SIRM ionospheric maps. The effective Sunspot Number is chosen to give the best fit between model (SIRM) calculation and actual measurements Ref [3].

These models reside on the DIAS server and are invoked to generate the maps of the ionospheric parameters and other information products. The DIAS products make use of the latest available ionogram data sets which reside on the DIAS server system. These real-time ionograms are automatically forwarded from the participating ionosonde stations.

DIAS results

The DIAS products available to specify the current conditions of the ionosphere over Europe include:

- Real-time ionograms from the contributing DIAS stations in a common format
- Daily values and plots of scaled ionospheric parameters, e.g. the critical frequency of the F2 layer (foF2), the lowest frequency reflected by the ionosphere which appears on the ionogram (fmin), the ratio of the maximum reflected frequency from the F2 layer over a 3000km range to the critical frequency of the layer (M(3000)F2), etc.
- Profiles of electron density versus height over each contributing DIAS station
- Regional maps showing the variation of relevant ionospheric parameters over the European area (i.e. maps of foF2, M3000F2, Maximum Usable Frequency (MUF) and electron density (Ne) at various specified heights)
- Daily plots of the Effective Sunspot Number which give estimates of the best fit between the Simplified Ionospheric Regional Model (SIRM) and the foF2 measurements from the DIAS sounder grid.
- Activity Index for foF2 providing an alert for current ionospheric disturbances.

Figure 1 presents an ionogram from Athens Digisonde in DIAS layout. The results of the automatic scaling are also given. Figure 2 is an example of a regional foF2 nowcasting map which has been generated using the ionospheric data from the DIAS sounders. The MUF produced assuming that the transmitting antenna is located in Madrid is given in Figure 3. Within DIAS a number of maps of this type are available covering the

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European region. DIAS users are also provided with a web interface which allows individual predictions to be generated according to the users' needs.

Figure 4 shows an example of the electron density map for a specific height. For this product, height is user-specified.

The products available in the Short-term Forecasts category include:

- Short-term ionospheric predictions (for periods of one to 24 hours ahead over Europe)
- European maps of Ionospheric Alert Indices for the foF2 which provide warnings for forthcoming disturbances.

The products available in the Long-term Predictions category include:

- Long-term ionospheric predictions (maps for the European area of foF2, M3000F2, and MUF)

Long-term prediction maps are available in the same format as the short-term nowcast and forecast maps shown in Figures 2 & 3.

Archived ionogram data is stored in the Standard Archiving Output (SAO) format which is ASCII text-based and readily accessible. The information and map products are presented in text and image formats.

On-line access to all available DIAS products and services is currently free to all registered users, directly through the DIAS system (<http://dias.space.noa.gr>) or indirectly through the DIAS project web site (<http://www.iono.noa.gr/DIAS>) for users who are not registered yet.

DIAS users' network

A network between the DIAS data providers and the users from the research, academic and industrial sector has been established. Continuous updates on the latest DIAS developments have been communicated through the circulation of monthly e-newsletters. Several meetings have been organised where evaluation discussions on the current version of DIAS prototype were held and contacts with all the members have been established through systematic surveys inside the DIAS network. This intense activity resulted to the identification of the avenues for the commercial exploitation of the DIAS products and services. The potential market sectors into which DIAS is able to supply its products and services have been identified and ranked according to their needs for specific DIAS products and to the existing competitive data sources. According to this ranking, the top users of the DIAS products are the defence industry, the civil aviation, the upper atmosphere researchers, the civil HF broadcast and the radio amateurs. Possible approaches to marketing were determined and possibilities for future development of DIAS have been considered in order to ensure the viability of the system in long-term future.

Conclusions

DIAS is the first Europe-wide project aiming at the collection of ionospheric observations from the European ionosondes and the development of added-value products for radio propagation services. The major strength of DIAS is that it can easily integrate new sets of observations in other areas around the world, can be easily updated by newly developed models and can follow the latest technological advance. These are the elements that enable the evolution of DIAS services over the next years and therefore ensure a long term future. In the near future DIAS could possibly expand its services through collaboration with existing ionospheric service providers on other continents, improving the accuracy for the worldwide specification of the ionosphere and contributing to the development of more accurate products for ionospheric prediction.

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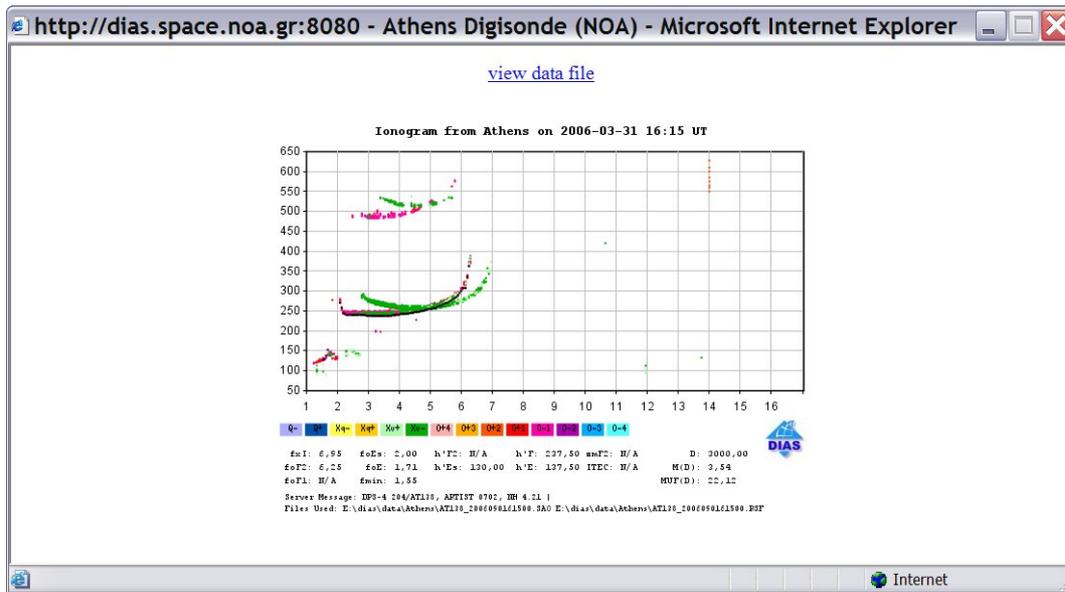


Figure 1: An ionogram from Athens Digisonde in DIAS layout. The results of the automatic scaling are also given. Clicking on the “View data file” the user can download the SAO file for the specific sounding.

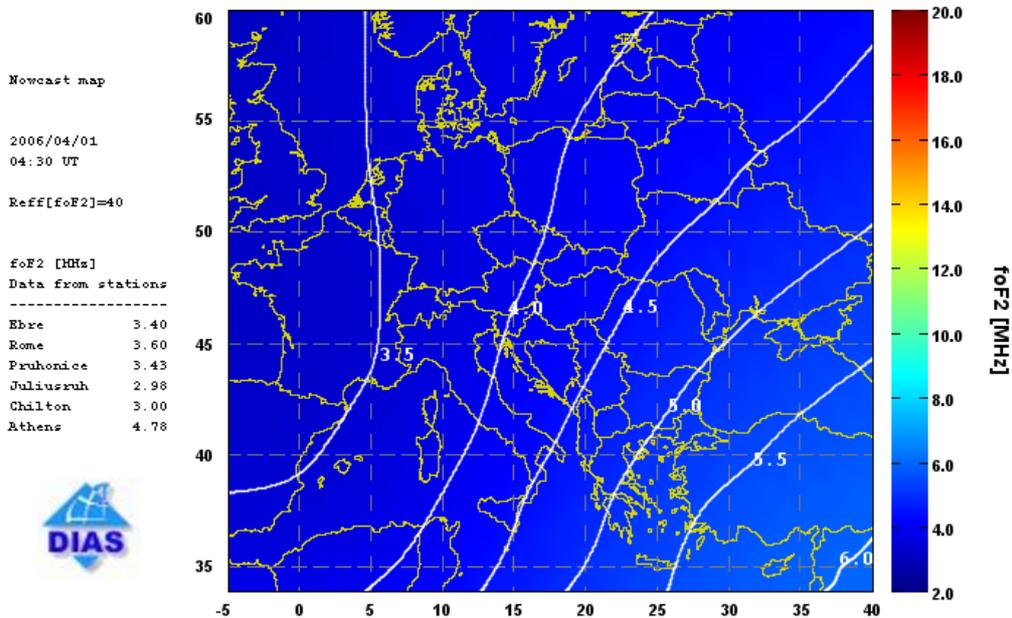


Figure 2: An example of a regional foF2 nowcasting map which has been generated using the ionospheric data from the DIAS sounders. The estimated value of the effective sunspot number as well as the real-time values of the foF2 parameter observed from the DIAS stations at the specific epoch is given on the left hand side of the figure.

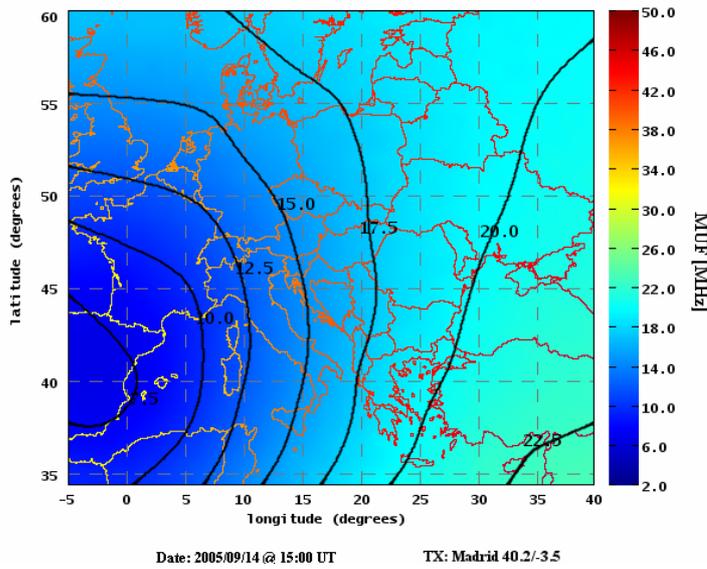


Figure 3: The MUF produced for nowcasting purposes, assuming that the transmitting antenna is located in Madrid.

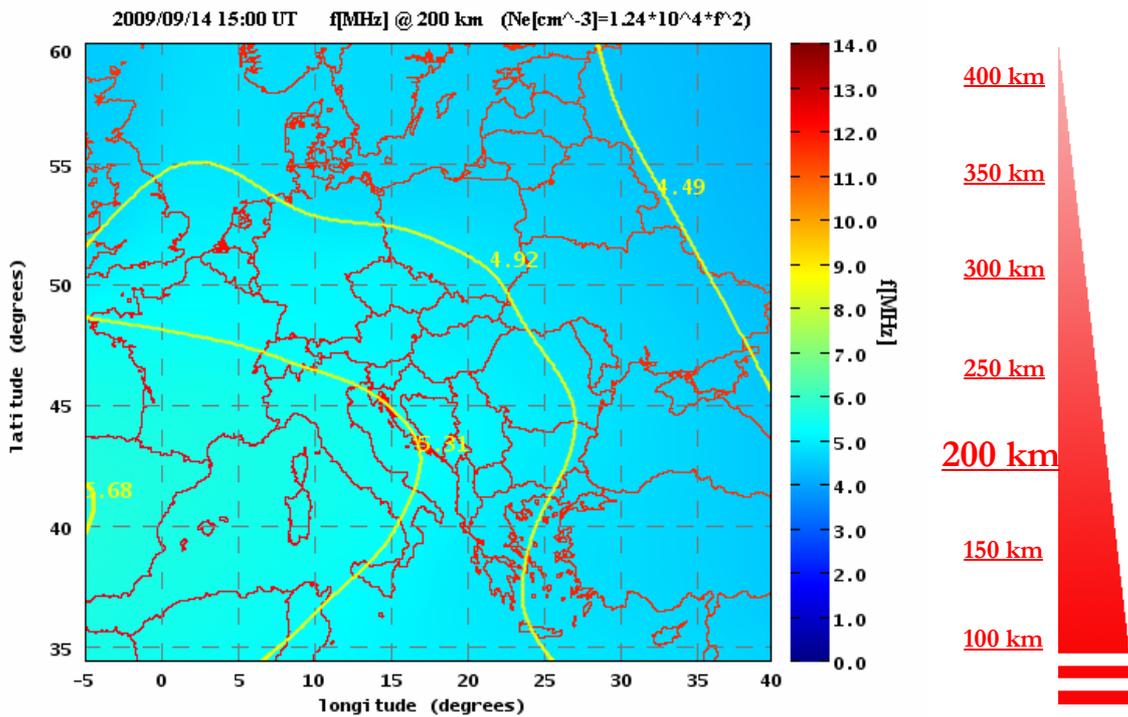


Figure 4: An example of the electron density nowcasting map over Europe at 200 km.