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The electronic Space Weather upper atmosphere (eSWua) project at INGV: advancements and state of the art

V. Romano[1], **S. Pau**[1], **M. Pezzopane**[1], **E. Zuccheretti**[1], **B. Zolesi**[1], **G. De Franceschi**[1], **and S. Locatelli**[2]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
[2]Volanet Srl, Rome, Italy

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Abstract. The eSWua project is based on measurements performed by all the instruments installed by the upper atmosphere physics group of the Istituto Nazionale di Geofisica e Vulcanologia, Italy and on all the related studies. The aim is the realization of a hardware-software system to standardize historical and real-time observations for different instruments.

An interactive Web site, supported by a well organized database, can be a powerful tool for the scientific and technological community in the field of telecommunications and space weather. The most common and useful database type for our purposes is the relational one, in which data are organized in tables for petabytes data archiving and the complete flexibility in data retrieving.

The project started in June 2005 and will last till August 2007. In the first phase the major effort has been focused on the design of hardware and database architecture. The first two databases related to the DPS4 digisonde and GISTM measurements are complete concerning populating, tests and output procedures. Details on the structure and Web tools concerning these two databases are presented, as well as the general description of the project and technical features.

Keywords. Ionosphere (Mid-latitude ionosphere; Polar ionosphere; Instruments and techniques)

1 Introduction

Data handling has become more and more important in the frame of ionospheric nowcasting, forecasting, propagation conditions warning, model development and evaluation (Stamper et al., 2004; Galkin et al., 2006; Wernik et al., 2007). In particular, space weather prediction systems rely on real-time information on ionospheric conditions, such as autoscaled parameters from the ionograms (Belehaki et al., 2005).

As the volume of data grows a database is indispensable for organizing and managing it: a properly designed database makes it easy to find a specific piece of information, even when the amount of information is large, reducing duplication and consequently the chance of inconsistency. In a non-database system the same information may be held in several files. This wastes space and makes updating more time-consuming. On the contrary, a database system minimises this effect and moreover can ensure only authorised access to the data. Users also have access to a wider range of data that was previously held separately and in different formats.

The electronic Space Weather upper atmosphere (eSWua) project, based on the data acquired by all the instruments installed by the upper atmosphere physics group of the Istituto Nazionale di Geofisica e Vulcanologia (INGV), was thought just to organize and standardize different kinds of historical and real-time measurements otherwise missing in different and not-related repositories.

The INGV monitoring activities can be divided into two main categories: middle-latitude and high-latitude observations. The middle latitude observations are carried on in Rome (Italy 41.8 N, 12.5 E), Gibilmanna (Italy 37.9 N, 14.0 E), and Chania (Greece 35.3 N, 24.1 E). The high-latitude observations are performed at the Mario Zucchelli Station (MZS, Antarctica 74.7 S, 164.1 E), Ny Ålesund (Svalbard, Norway 78.9 N, 11.9 E) and Longyearbean (Svalbard, Norway 78.2° N, 16.0° E).

The eSWua system does not want to enter in competition with other systems already existing like the European WDC (Stamper et al., 2004) or the DIAS (Belehaki et al., 2005). The INGV project aims to support the international data archives and projects where the interoperability of the system and effective data access are necessary requirements, such as Virtual Observatories (http://www.egy.org), and to do this the first natural step to pursue was to structure all the INGV data as a database.

Correspondence to: M. Pezzopane
(pezzopane@ingv.it)

What makes eSWua unique and useful is the development of a scintillation database that is also able to collect data coming from receivers installed by other scientific institutions. Again, the possibility given to the user in visualizing the corresponding scintillation data as polar and linear plots (choosing different thresholds of visualization) is unique and very useful to have a prompt idea of the scintillation phenomena characterizing the high latitudes.

In fact, besides developing and maintaining the database, one of the ideas for the future is to give the user the ever-new possibility of plotting interesting patterns that are not visualizable anywhere else. For instance, it would be very interesting if the system could generate ionogram height-time-intensity analysis plots (Haldoupis et al., 2006).

This work describes the technical features, software and hardware, of the whole project, as well as the state of the art. Moreover, details on Web tools concerning ionospheric and scintillations data treatment, and user policy management are presented.

2 Benefits and motivation

The eSWua system arose as a resident archive, developed and maintained by engineers and scientists of the INGV who are best familiar with the issues related to the instruments and the related acquired data. eSWua is a system which is continuously evolving and a resident archive lets the INGV administrators have the possibility to make any kind of modifications and include added value products without depending on outsourcing IT professionals who do not have a thorough knowledge of the subject. The eSWua is the outcome of a big effort of manpower, time and funds, motivated by the awareness that geoscience has to rely on structured digital data and on appropriate scientific procedures developed ad hoc by experts, opened and shared among the international community. To fulfill this aim the system is designed to be ready in the next step to guarantee the interoperability with similar systems. With regard to this issue XML outputs are planned.

The other requirements that are taken into account in the design process are:

- Simplicity of use. Users are provided intuitive and easy tools.
- Interactivity. The quality concerning response times and messages is high. To maintain a small latency introduced by the network, the quantity of information is minimized.
- Scalability, flexibility and expandability. The system is able to handle the increasing number of users and data diversification.
- Compatibility. The system works in the same way under different platforms (Unix, Windows, Macintosh).
- Multi user management. Different users can access simultaneously.
- Remote management. Database handling and administrators access are possible remotely.
- Storing information capability and formats. Measurement results are stored in different formats, according to the datum characteristics.
- Output capability. Database structured data are retrieved and presented in different popular formats (TXT, HTML, XML).
- Web updating and publishing. The system updates information in order to avoid differences between the database and the Web site.
- Users profile and accessibility. Reserved information is protected. Users have the proper access privileges.
- Access, profiles, users management. Each server and the whole system have an administrator managing different privileges and profiles.
- Automatic control and information statistics production. The system continuously monitors the data flow and processing to produce informative statistics.

3 System characteristics

The system's architecture is reported in Fig. 1. The eSWua database is populated with the data provided by the following instruments installed and managed by the INGV:

- a Digital Portable Sounder 4 (DPS4) produced by the University of Lowell, Massachusetts, USA (Reinisch and Huang, 1983) operating in Rome since 1998;
- three Advanced Ionospheric Sounders designed and developed by the INGV (AIS-INGV) (Zuccheretti et al., 2003; Pezzopane and Scotto, 2005), installed in Gibilmanna in 2002 (Baskaradas et al., 2005), in MZS in 2003 (Romano et al., 2004) and in Rome in 2004;
- a Radio Chirp Sounder (RCS) sweeping HF receiver for oblique sounding installed in Chania in 2004 and an Improved Radio Ionospheric Sounder (IRIS) oblique chirp sounder installed in Rome in 2005, both of them receiving the ionospheric echo from Inskip, United Kingdom (54.0 N, 3.0 W) (Zolesi et al., 2007);
- four GPS Ionospheric Scintillation and TEC Monitor (GISTM) receivers specifically configured to measure amplitude and phase scintillation from the L1 frequency GPS signal, and ionospheric TEC from the L1 and L2 frequency GPS signals (Van Dierendonck et al., 1993).

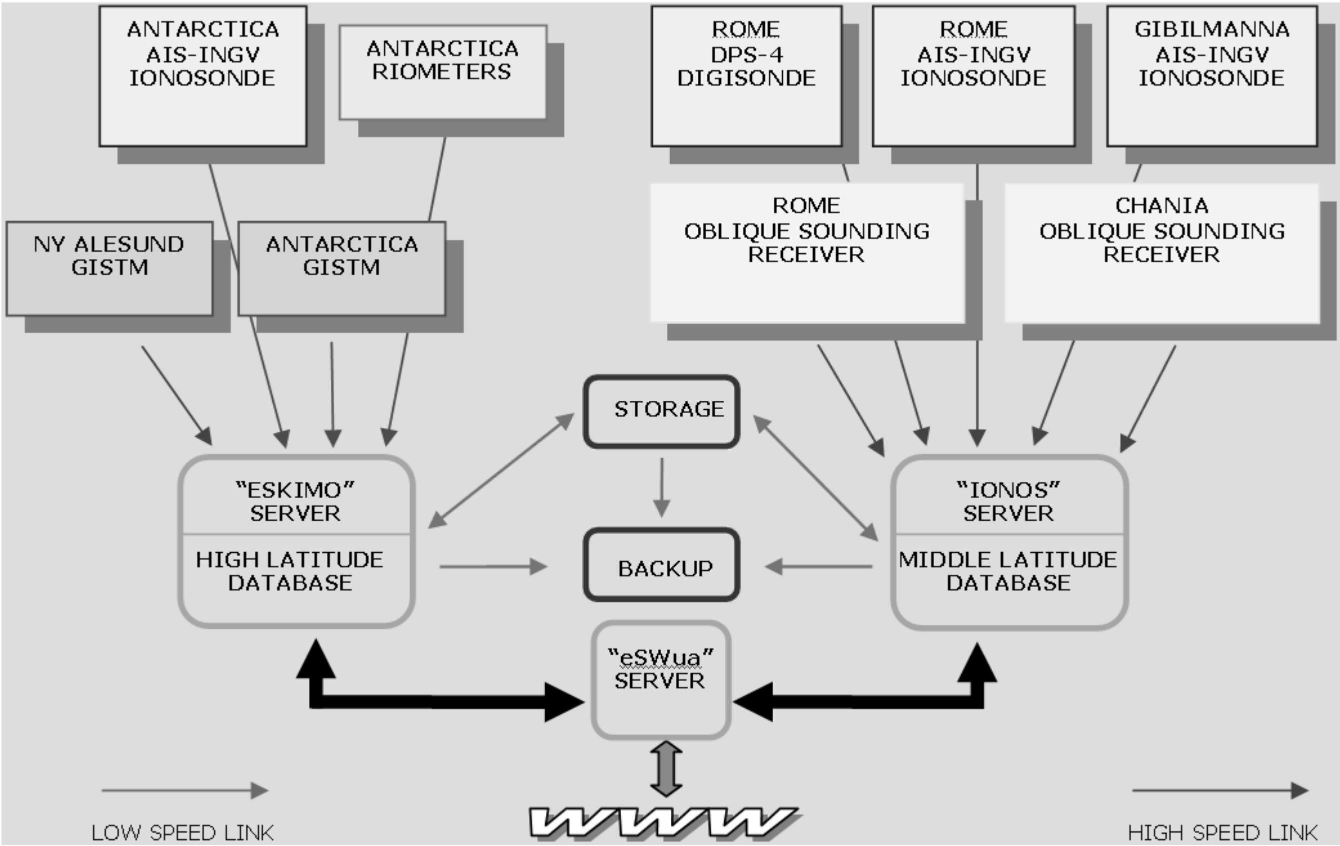

Fig. 1. Data flow and system architecture.

Two were installed at the "Dirigibile Italia" Arctic Station in Ny-Ålesund between 2003 and 2004 and two more were installed in Longyearbean and MZS in 2006 (De Franceschi et al., 2006);

– three solid state La Jolla riometers (Chivers and Prescott, 1967), one at 30.0 MHz and two at 38.2 MHz, operating at MZS since 1993.

The data treatment system is based on three servers, *eSWua*, *Ionos* and *Eskimo*. The first, *eSWua*, hosts the system's Web site and it is devoted to the user interface management. The other two servers are dedicated to collect in real-time all the data coming from the INGV upper atmosphere stations and to arrange them in different databases. For safety reason the data flow is based on point to point links, moreover, *Ionos* and *Eskimo* are not a public front-end. *Eskimo* and *Ionos* are devoted to the polar and to the middle-latitude data, respectively. The functions of the two servers are:

– to receive data across dedicated lines;

– to automatically populate the database (one for every kind of data);

– to manage the queries coming from the *eSWua* server in order to process user requests and to make different outputs available;

– to guarantee a protected access to the databases' tables and data files;

– to manage the raw data storage.

The backup process, which is conducted by a dedicated system, is incremental and does not need to halt any databases.

The applied technologies for the hardware configuration and software development are reported in Table 1.

4 State of the art

The breakdown schedule is reported in the Gantt diagram (Fig. 2). The project started in June 2005 and is planned to last till August 2007, with the full open access to the Web site. In the first phase the major effort has been focused on the design of hardware and database architecture. The first two databases related to the DPS4 digisonde and GISTM measurements are complete for what concerns populating, tests and output procedures. A dynamic web site has been opened for a real-time access to these data (http:

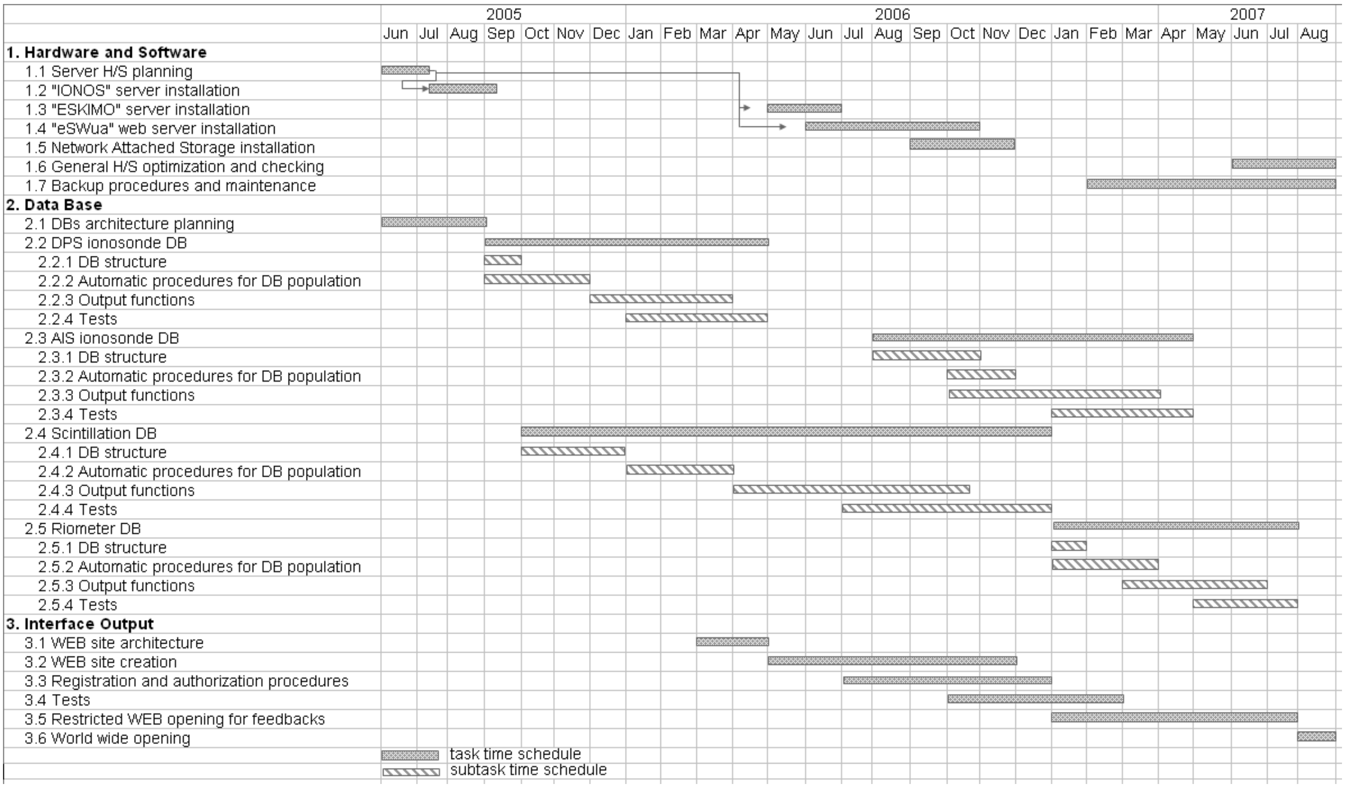

Fig. 2. Gantt diagram representing the breakdown schedule of the project.

Table 1. Hardware and software technologies used to develop the eSWua framework.

Item	Technology
Servers	HP Proliant DL 360–3.0 GHz
Storage	Extreme Raidtec
Backup	QNAP 4300S – Raid serial ATA 2 TB
Operative System	Windows Server 2003
Database	MySQL 4.1.12
Database Populating	PHP 4.4.X
Automatic Data treatment	Visual Basic 6.0
WEB Interface	PHP, html

//www.eSWua.ingv.it). In order to check the connection reliability and the outsiders connection, a statistics report is in progress. At the moment an automatic procedure to register the accesses to any page of the site has been developed. The description of the general guidelines of the ionospheric and scintillation databases follows.

4.1 Ionospheric database

This database contains ionospheric parameters obtained by scaling ionograms (Piggot and Rawer, 1972) that are the raw measure of the radio sounding performed by a dedicated radar system called ionosonde (Bibl and Reinisch, 1978). In modern digital ionosondes the ionogram is stored as a file to be scaled, manually or automatically, while analogical ionosondes produce pictures that, after printing, are manually scaled. The historical and real-time data coming from the ionospheric stations of Rome, Gibilmanna and MZS were structured. Each station, in a different period, was equipped with different ionosondes. Regarding the Rome station, ionograms are now produced by the DPS4 and AIS-INGV ionosondes. Both of them are able to give as output an automatic scaling of the recorded trace. The Rome manual scaling is performed within a few days from the sounding on the ionograms recorded by the AIS-INGV. Concerning the Gibilmanna station the ionosonde used is an AIS-INGV, able to give as output an automatic scaling of the recorded trace, which is also manually scaled. At MZS, again, an AIS-INGV ionosonde is presently installed. In this case the ionosonde is not able to give as output an automatic scaling of the recorded trace, which is only manually scaled within a few days from the sounding.

The ionospheric database is structured in monthly tables. For each scaling procedure (automatic or manual) different tables are populated. Each record contains the information coming from a single sounding identified by a time marker that univocally represents the sounding time. These tables

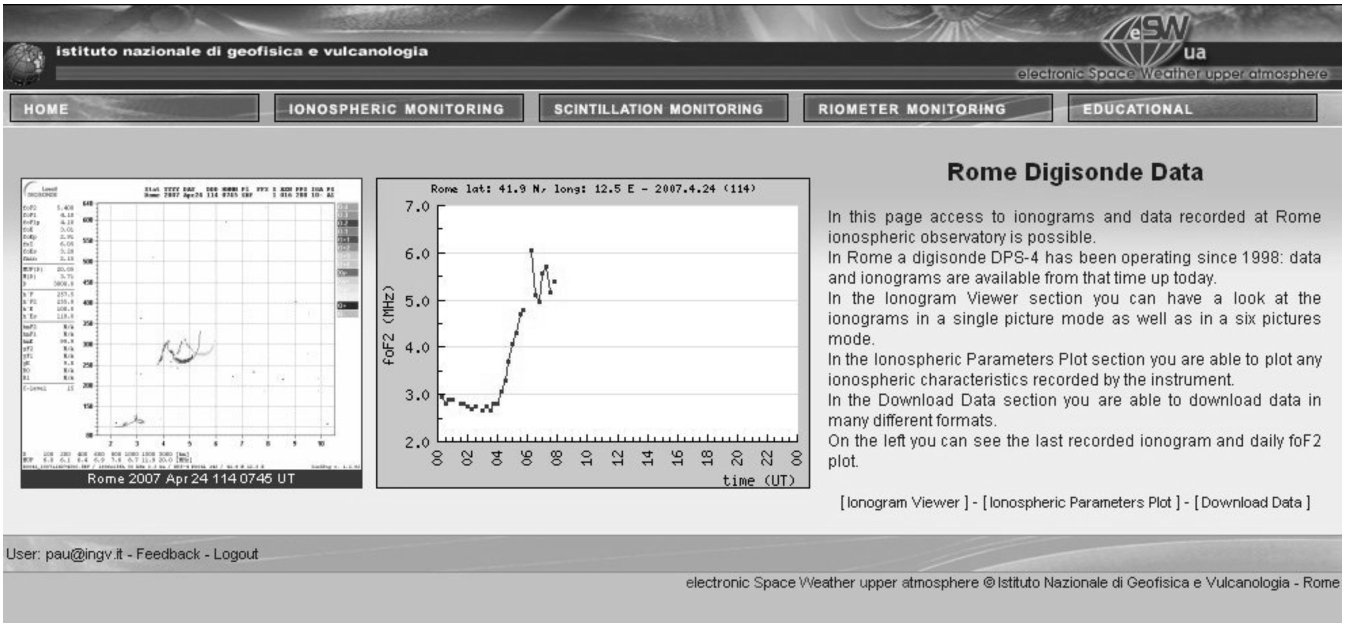

Fig. 3. Rome DPS4 ionospheric vertical sounding main page, continuously updated with real-time data.

are constituted by columns in which both sounding settings and ionospheric parameters are stored. The number of ionospheric parameters depends on the type of ionosonde considered. More details about the data are differenciated according to the kind of data and the ionosonde producing them. Autoscaled data from DPS4, produced by ARTIST (Reinisch and Huang, 1983), are organized into tables containing 56 ionospheric characteristics (including electron density profile). Autoscaled data from AIS-INGV, produced by Autoscala (Pezzopane and Scotto, 2005), are organized in tables containing 15 ionospheric characteristics. Manually scaled data are organized in tables containing 14 ionospheric characteristics including qualitative and descriptive letters. Ionogram pictures and raw data files are also addressed in the database. All the instrument-specific data and the station constants are stored in a further table.

Concerning the populating procedure, there is a distinction between manual and automatic scaling. In the automatic scaling, digital ionosondes send results continuously to the proper server (Fig. 1), where they are processed to populate the database. Regarding the manual scaling, files with ionospheric characteristic are stored temporarily in a folder; when a period of a month of data is reached PHP scripts, run by an operator, populate the database.

4.2 Scintillation database

This database contains scintillation values obtained by GISTM receivers. INGV installed three receivers in the Arctic and one in Antarctica. Every 15 min a binary file is produced by each instrument and sent to the *Eskimo* server. The measurement is realized with respect to every visible GPS satellite with one-minute sampling rate. The measure produces a total of 35 navigational and observational parameters that are real-time structured in the database for every station. The GISTM station performs the 50 Hz sampling, too; in this case to have a fast access to the raw data the files are stored by the system and only addressed in the database. Considering the amount of data collected by the four instruments, only a database organization allows extrapolation and comparison of the interesting events. In this way the correlation between data of different instruments is also possible. An extraction procedure automatically runs and converts the binary file into ASCII format. A PHP batch procedure reads this file and populates the database. Data for every GPS scintillation receiver are organized in monthly tables. In these tables all measured values are stored along with some calculated parameters useful to a spatial localization of the measure. Each record represents all the parameters at a certain time with respect to a satellite. Different records can be referred to at the same time because the records are related to different satellites. Data are structured in tables containing 29 measured parameters and 6 calculated values. All the instrument-specific data and the station constants are stored in a further table. For the database populating each instrument has its own automatic procedure.

5 Web site and database interaction

The eSWua home page (http://www.eSWua.ingv.it) allows the registered users to log in and the new users to register. The site offers a free registration in order to evaluate which

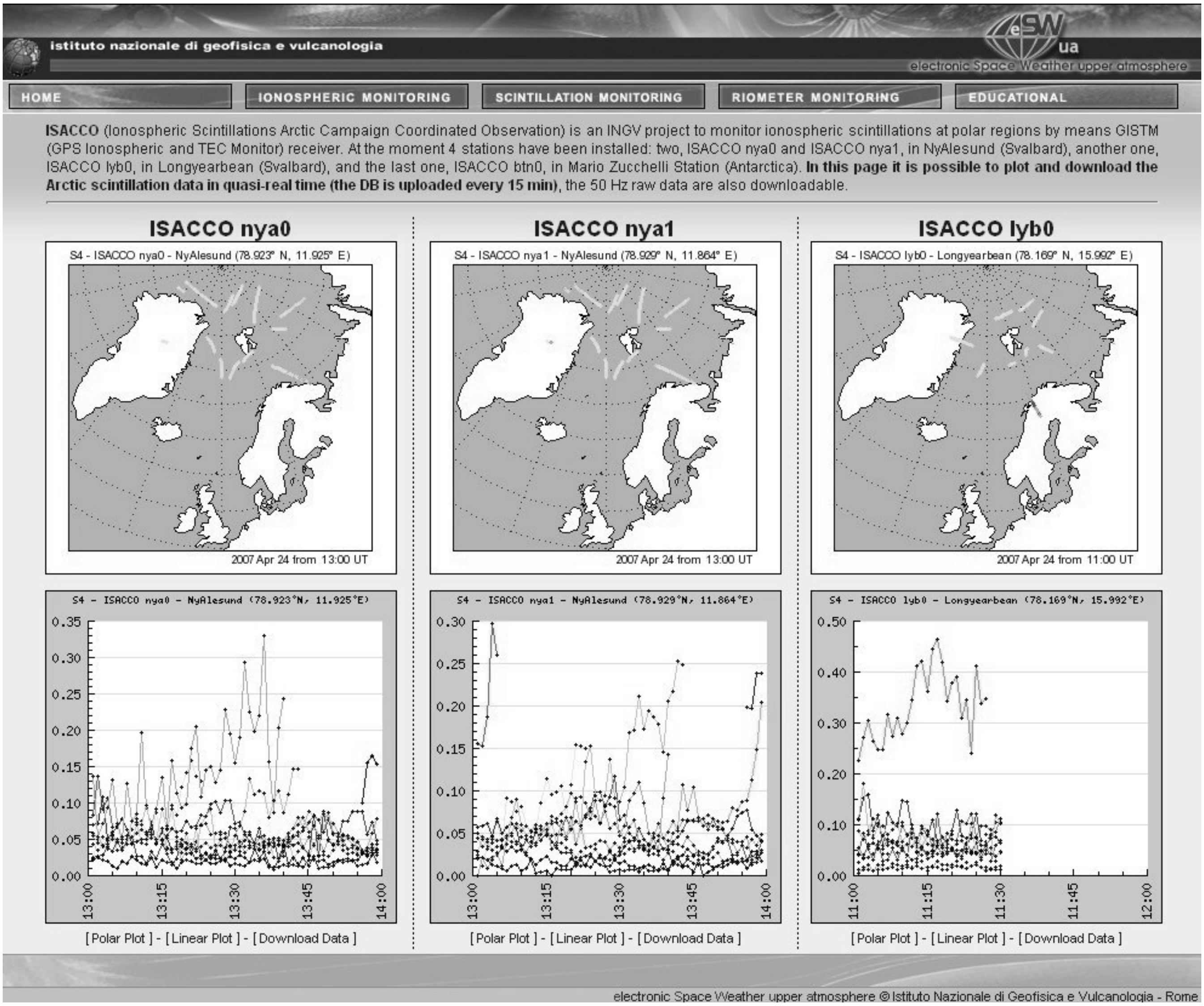

Fig. 4. Arctic Scintillation main page, continuously updated with real-time data. The columns represent the three GISTM receivers operating at Svalbard Islands.

kind of data or plots are used by the different users. Registered users are organized in three levels, allowing the access to different sections of the site; the higher the level is, the greater the capabilities are in accessing the public resources.

The site is organized into four main sections whose titles are "Ionospheric monitoring", "Scintillation monitoring", "Riometer monitoring" and "Educational", respectively. Each main section is divided further into sections according to a geographical criterion. Hence, under the title "Ionospheric monitoring" the user can choose between "Italy", "Mediterranean Area" and "Antarctica", under the title "Scintillation monitoring" the user can choose between "Arctic" and "Antarctica", and under the title "Riometer monitoring" the user can choose "Antarctica".

In the next two paragraphs a short description of the working sections is given.

5.1 Ionospheric monitoring section

Once logged in, choosing "Italy", under the "Ionospheric monitoring" section, the user has the possibility to choose between two ionospheric stations, Rome and Gibilmanna. For the Rome DPS4 station the real-time ionogram and *fo*F2 daily plot are shown to give the user a quick look at the present ionospheric conditions (Fig. 3). From such a page it is possible to select the "Ionogram Viewer", the "Ionospheric Parameters Plot" or the "Download Data" section.

Through the "Ionogram Viewer" link, ionogram pictures can be surveyed.

Through the "Ionospheric Parameters Plot" link, the user can plot several ionospheric characteristics.

Through the "Download Data" link, data can be downloaded in different formats.

5.2 Scintillation section

The above described logical structure is also used for the "Scintillation monitoring" section. The user can access the "Arctic" and "Antarctica" region data and in both cases he reaches a page containing the latest available hourly polar and linear plots (Fig. 4). From this page he can click one of the following links: "Polar Plot", "Linear Plot", or "Download Data".

Through the "Polar Plot" link, polar plots can be surveyed.

Through the "Linear Plot" link, linear plots of the selected measured parameters can be surveyed.

Through the "Download Data" link, data can be downloaded in different file formats.

6 Summary

The INGV manages different kinds of observations of the upper atmosphere and has been collecting digital data for several decades. This large amount of information is now organized in a proper database, able to contribute to scientific and technological improvements at national as well as at international levels. The eSWua system is capable of supporting the acquisition, elaboration, evaluation and archiving of multi-instrument observations of the ionized atmosphere. The COST296 Action (http://www.cost296.rl.ac.uk) offers the possibility to share the expertise of excellence in Europe in order to test the potentialities of the system, which can be, in turn, extended to host other data and scientific tools provided and suggested by the partners of the same Action. In the frame of international collaborations the eSWua is contributing to the projects where the interoperability of the system and effective data access are necessary requirements, such as Virtual Observatories (http://www.egy.org), ICESTAR (Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research, http://www.scar-icestar.org/) and SIRIA (Information System for the Italian Research in Antarctica) (Piervitali et al., 2004). The eSWua is the outcome of a large effort of manpower, time and funds, motivated by the awareness that geoscience has to rely on structured digital data and on appropriate scientific procedures developed ad hoc by experts open and shared among the international community.

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