CHARACTERIZATION OF THE GEOMAGNETIC FIELD BY ANALYZING THE DATA RECORDED AT THE SURLARI GEOMAGNETIC OBSERVATORY

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ABSTRACT

In our paper, we have described the steps to analyze the geomagnetic field's morphology, and the results of these, that will be included together with other multidisciplinary studies for the space weather forecast within the project in which we are partners.

Based on data processing are calculated the gradients of each component, as well as, spectral, statistical and correlation analyzes. All of these parameters are part of the geomagnetic database.

Web interface for the database meets the different handling needs of collected, raw or processed data. The server-side programming language used for design is php.

This allows us to select different periods for which access to stored data, required for different search filters and different parameters or data from different time periods can be compared.

For a more in-depth analysis of the stored data, through JavaScript programming language can be draw graphs for different parameters.

Access to the web interface can be done with or without authentication, depending on the need to ensure the security of certain data collected, stored and processed.

The application is scalable for different devices that will access it: mobile, tablets, laptops, or desktops. This application will be included in a project website „Institutional capacities and services for research, monitoring and forecasting of risks in extra-atmospheric space”, component project: „Space Weather", acronym: SAFESPACE, within the grant of the Romanian Ministry of Research and Innovation, CCCDI – UEFISCDI, project Nr.16PCCDI/2018.

Keywords: *Geomagnetic Observatory, database, data in real-time, data acquisition, data processing*

INTRODUCTION

At the same time, a significant development in the procedures of processing primary data has been registered, based on standardized programmes. The new stage of this fundamental research, largely applicable in various fields, is also marked by the simultaneous observation of space-time distribution of terrestrial electromagnetic field by means of stations set on satellites circling on orbits around the Earth.

In Romania, fundamental research in this field has developed within a special unit, Surlari National Geomagnetic Observatory (SNGO), acronym: SUA in INTERMAGNET, in which have followed two main objectives [1], [2]:

- a permanent observation of planetary magnetic field within a world net of observatories;
- highlighting some local disturbances, through electromagnetic induction, related to the geological structure of our country's territory.

Data regarding geomagnetic fields all over Romanian territory will be revaluated, along with rendering evident some peculiarities of very long-term variations, which require long time series, operation possible only in a few observatories with a long and continuous activity [3]. SNGO's current data base - covering over 75 years of non-stop observation of the transitory part of the geomagnetic field – is an important patrimony, both for national and for planetary research. We should mention that out of the 180 observatories and fundamental stations forming the current world net for monitoring terrestrial geomagnetic field, only 50 stations (SNGO included) can deliver complete time series comprising seven solar activity cycles [3], [4], [5], [6], [7], [8].

REMARKS ABOUT SURLARI GEOMAGNETIC OBSERVATORY

Geomagnetic field study in Romanian stations has started with irregular measurements, in late XIX-th century. In 1943, the foundation of SNGO marks the beginning of a new era in the systematic study of geomagnetic field by a continuous registration of its variations and by carrying out standard absolute measurements in a fundamental station. Observatory location was thoroughly established, so that meets the geomorphological and technological criteria. SNGO is located in Căldăruşani - Surlari astro-geodetic polygon, in an area without magnetic field anomalies or significant local heterogeneity of electrical conductivity in the basement and a sufficient distance from major industrial sources of disturbance. The Observatory covers an area of 3.56 hectares and comprises seven buildings and an underground laboratory for geomagnetic sensors. Inside are installed specialized equipment's to multiparametric monitoring of fields of the Earth. These buildings were made during 1943-1969. The underground laboratory and the main buildings were renovated and modernized in 2006-2008 [3].

The design of the special geomagnetic recording laboratories was made after some well verified. Inside laboratories were built 18 specially designed pillars embedded deep in the ground, which are mounted high-resolution sensors.

In figure 1 and 2 are show two photos with General view and absolute measurement laboratory in SNGO.

Fig. 1 - General view in SNGO

Fig. 2 Absolute measurement laboratory in SNGO

Lately, SNGO has been concerned about:

- permanent knowledge of the structure and evolution of transitional geomagnetic field during several solar cycles [1], [2], [3];

- providing highly accurate absolute values of the magnetic field direction and intensity;

- characterization of the planetary and local "magnetic state" by the regular computing of geomagnetic activity indices;

- regular comparison of the base levels of geomagnetic records (national magnetic standards) to other planetary observatories;

- study of various temporal geomagnetic variations with periods in a very wide range in time from seconds to hundreds of years;

- determining the spatial distribution of the geomagnetic field, mainly at the national level and integrate these images into continental or planetary maps. These distributions are obtained by repeated measurements in a network of points evenly distributed across the country. Determined values are used to obtain the secular variation of the normal geomagnetic field and binding of magnetic maps made in different times;

- contribution to establishing periodic coefficients of the IGRF (International Geomagnetic Reference Field) in the IAGA with shaping local peculiarities reported in our country.

Since 1998, the fundamental geomagnetic station of Romania, SNGO, was admitted as an planetary observatory in INTERMAGNET program fulfilling main obligations imposed in this capacity, mainly oriented towards the major aspects of planetary field, axis and the changes of Gaussian dipole moment , the International

Geomagnetic Reference Field - IGRF, the level of solar activity and disturbances related to the relationship Sun - Earth, the solar wind interference and interplanetary magnetic field, or structure of convection currents in the outer core - Earth's asthenosphere [4], [5], [6], [7], [8].

Permanent recordings made on SNGO or in stations temporarily installed in Romania are useful to eliminate variations with external causes, leading to application of corrections to the magnetometry survey in order to increase their accuracy because when is measured weak geomagnetic effects, these cuts are absolutely necessary for accurate localization of abnormalities of economic interest.

NETWORK INFRASTRUCTURE AND DATABASE OF SNGO

The goal of network infrastructure creation is to facilitate access to data recorded in a single format, automate pre-processing, and obtain a unique time basis (via GPS) for all data.

The operating system chosen to support the services provided is the distribution of Linux OpenSUSE 11.1 for services running on x86 machines and the services hosted on the Cisco router run under Cisco IOS 12.4T

Short description of network and infrastructure features at the SNGO:

- NAT local network access implemented natively by the Cisco-880 router
- VPN Remote access server in the Observer's local network for users located in other locations implemented through Cisco IOS 12.4T
- DHCP automatic configuration of network settings implemented with ISC dhcpd 3.1.1
- DNS address resolution by name and vice versa implemented with ISC BIND 9
- Integrated LDAP authentication of users in the local network implemented with open ldap 2 2.4.12
- NTP clock synchronization service for all computers connected to the local network implemented with ntpd 4.2.4
- Database server for storing data from all Surlari Geomagnetic Observatory acquisition systems implemented with MySql 5.0.67
- Web server hosts the observatory's web site deployed with Apache 2 2.2.10

2) Automatically, periodically (e.g., averaged over 5 seconds or 60 seconds) to the Web server.

- FTP server file transfer services for Intuitive users using Intranet vsftpd 2.0.7
- File server for general use file storage with Samba 3.2.4

For implementation, these services have been grouped into 4 categories, taking into account their specificity, the need for hardware resources to run, and critical dependency between them. For implementation, the solution was chosen as each group to run on a separate server.

Cisco-880 router - runs NAT and VPN server services (already implemented and active)

netserv * - server for common network services: DHCP, DNS, LDAP
dbserv * - database server (Fig.3)
filer * - file server
webserv * - Web server and FTP

To reduce costs and reduce the number of computers installed, all are virtual machines running under VMware Server 2 on a single physical server for high reliability (RAID 1 for dual hard drives, dual NIC mounted in fail-over architecture, UPS with monitoring software).

Modernization of the network infrastructure has been carried out so that it can provide all the services necessary for the exploitation (figures 3 and 4).

The software package consists of the following components:

- SQLServer.VI on the database server is designed to transmit measured values in two ways:

1) upon request, to applications installed on computers of different users; users can log in with a username and password to access the data stored on the database server;

2) Automatically, periodically (e.g., averaged over 5 seconds or 60 seconds) to the Web server.

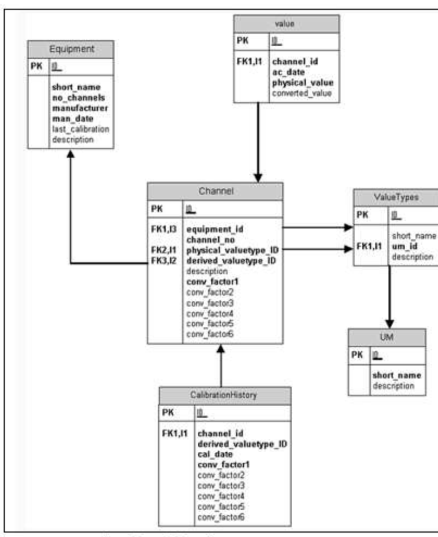

Fig. 3 - Sketch of the data server. Description of each unit within the data server

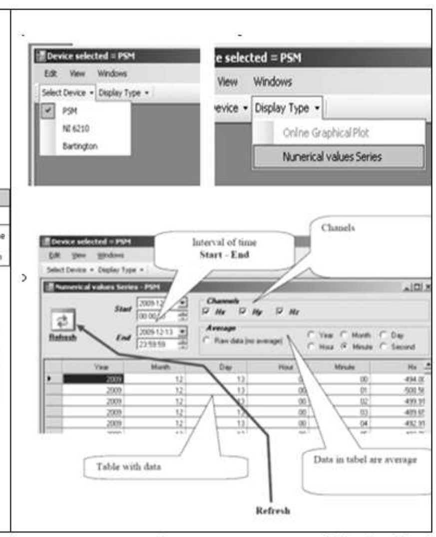

Fig.4 - Schematic overview of the database acquisition and management program.

Client VI, with multiple installations on different users' computers, has the role of allowing them to create on their own computers text files containing measured values retrieved from the database server (figure 3 and 4);

This allows the user to select the start and end moments of the time period for which the SQL Server VI, application will be requested, copy the measured values;

The user can specify, where appropriate, the path and file name in which the measured measurement values transmitted by the SQL Server VI application are saved;

- Web Server VI is installed on the Web server and receives the measured values, periodically transmitted by SQL Server VI and will save them in text files;

The files are daily, the file name is DD-MM-YY, and the files within a month will be stored in the same folder, the monthly folder name being MM-YY.

- Java Client VI, is installed on the Web server and is called by the actions of the various web page visitors and allows viewing of measured values in graphical form.

These software applications respect the SNGO internal network and public network connections, thus centralizing data acquisition and online transmission on Web Server.

Standard processing of geomagnetic data according to INTERMAGNET requirements includes calculating the average at one minute of Geomagnetic components.

Values and obtaining provisional data files, establishing the base level of records as well as adopting the baseline level and making definitive data.

This infrastructure and organizing of database from SNGO allow us to monitor and make all processing procedures of data according to geomagnetic observatories reequipments.

PRINCIPLES OF PROCESSING USED FOR CHARACTERIZATION OF THE GEOMAGNETIC FIELD

By continuous monitoring of the geomagnetic field, discrete time-dependent signals for each component are obtained.

Depending on the predictability of the evolution over time, these signals cannot be considered deterministic signals with predictable evolution. Simple deterministic signals can be fully specified by a small number of parameters (amplitude, frequency, and phase).

The geomagnetic signals acquired can be considered as random signals, with a predictable evolution only in a probabilistic sense [9], [10].

The statistical dimensions for characterization of the localization and dispersion of a random variable are: mean value, variance, and quadratic mean value.

A stochastic process results from the variation in time of random size, i.e. a random function of time, x (t), whose value for each moment considered will be a random size.

The main statistical parameters of a stochastic process are: average value, dispersion (variance), mean square value, autocorrelation function and autocovariance function.

Unlike the statistical parameters of random variables, which are numbers, the statistical parameters of stochastic processes are time functions.

Additional statistical parameters, able to characterize the internal structure of the process, are the function of autocorrelation and the function of autocovariance.

These parameters characterize, from a numerical point of view, the degree of dependence between process values that are at different time intervals. The functions of autocorrelation and autocovariance are deterministic.

One of the most used methods for determining the characteristics of a signal and evaluating its informational content is to analyze the spectrum of the signal. For a deterministic process defined by a given signal, a signal decomposition can occur in a large number of harmonic signals of various frequencies and amplitudes.

Modern approaches to spectral analysis are designed to overcome some of the deformations produced by classical methods and are quite effective especially for short analysis segments.

CONCLUSION

Preliminary data in the form of average values at one minute of recorded components contained in daily files that have the extension code of the observatory are corrected with the value of the base level adopted for each component for that day.

Files obtained in this way are processed with an application that converts them from daily text files into monthly binary files containing the minute averages of recorded and corrected components.

The final data set delivered to Geomagnetic Information Node (GIN) at the beginning of the year following the one for which they are calculated will contain 12 monthly binary files with geomagnetic components and magnetic activity indices for each month, a geomagnetic field component annual file, a file with the basic and calculated values for geomagnetic field records and a readme file containing data on the recording technique, the absolute measurements used in the observatory and the personnel carrying out these works.

The components of the geomagnetic field measured in the SNGO are: North (Hx), East (Hy), vertical down (Hz), declination (D), inclination (I) and the total component. From any of these three components, the four other components can easily be calculated by simple trigonometric relationships.

The geomagnetic data processing steps include correcting the values of the components of the geomagnetic field purchased with the vector magnetometer by adding the base values of each component to the values acquired by the flux-gate magnetometer. Then calculate the minute-averaged values of the corrected components with the provisional baseline value and the baseline by interpolation with a third-order polynomial function of the absolute measurement values.

Another step is to determine the ramps and spikes recorded and to remove them from the dataset or to replace them with data from the second acquisition system.

All modern techniques implemented in the SNGO processing module attempt to make advantage of any known information about geomagnetic signals for the good characterization of the geomagnetic field.

A new concept for the database in SNGO includes the following modules:

Database Module

A database will be designed in the MYSQL language to store both the gross measured values - F, H, X, Y, Z, D and I (at variable frequencies) and those resulting from processing in the forecasting module.

Application Hosting Module (Apache Server)

This module will host an application designed in php and javascript (Database Interface Database). To be able to do this, the Apache Server will have the mod_php enabled.

The web interface for the database

The interface will meet different handling needs of collected, raw or processed data. The server-side programming language used for design is php.

This will allow us to select different periods for which access to stored data will be required, different search filters (based on different parameters), or data from different time periods. For a more in-depth analysis of the stored data, javascript will draw graphs for different parameters.

Access to the web interface can be done with or without authentication, depending on the need to ensure the security of certain data collected, stored and processed.

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