Institute of Geodynamics
Romanian Academy

Project

"**The geomagnetic field under the heliospheric forcing. Determination of the internal structure of the Earth and evaluation of the geophysical hazard produced by solar eruptive phenomena**"

IDEI Program, Contract 93/5.10.2011

Stage I, December 15, 2011

Synthesis

The proposed research aims at achieving an understanding of the space weather effects on conducting structures inside the Earth and on the surface electric field, with applications to a better knowledge of the internal structure of the Earth at continental (Europe) and country scales, on one hand, and to estimating the geophysical hazard of space weather at midlatitudes, on the other. The main objectives are:

- To derive the magnetic and electrical properties of the terrestrial lithosphere and mantle at continental and Romanian territory scales;
- To analyze solar eruptive processes and solar wind components responsible for geomagnetic hazardeous activity (geomagnetic storms and substorms) in the time interval 1964-2014;
- To model the geoelectrical field at the Earth's surface as produced by various magnetospheric and ionospheric current systems;
- To evaluate the geophysical hazard for technological networks, associated to variations of the geolectric field during geomagnetic disturbances linked to the interaction of coronal mass ejections and high speed solar streams with the magnetosphere.

The current report is structured as follows, according to the working plan of the project.

In *Chapter 1*, entitled "**Review of geomagnetic data acquired between 1970 and 2010 by measurements in the National Secular Variation Network**," previous results in monitoring the evolution of the geomagnetic field on the Romanian territory are presented.

Measurements at the repeat stations are to be found in the field books in the archive of the Natural Fields Department of the Institute of Geodynamics. They have been used both to determine the distribution of the normal field on the Romanian territory and for the description of the secular variation of the main field. Till 2001 measurements were financed from the budget of several research institutes to which the group doing measurements belonged (Center for Geophysical Research of the Romanian Academy, Institute of Applied Geophysics, Institute og Geology and Geophysics, Institute for Earth Physics, Institute of Geodynamics of the Romanian Academy), and in the last 10 yearsthrough contracts won in the national calls of the Ministry of Education and Research and Romanian Academy, as follows:

1. Regional characteristics of the evolution of the main geomagnetic field and of the reference (normal) field in Romania; MENER Project 033/2001, 2001-2004
2. Space-time evolution of the main geomagnetic field on the Romanian territory in the context of the European continent; Romanian Academy Grant 76/2005, 73/2006, 2005-2006
3. Long-term variability of the terrestrial magnetic field in relation to physical processes in the heliosphere; Project PN II IDEI 151/2007, 2007-2010
4. Heliospheric variabilities and their impact on components of the terrestrial system; Project PN II Parteneriate 81-021/2007, 2007-2010

The last two contracts allowed tackling, from an enlarged temporal perspective, of some aspects related to the long-term evolution of the geomagnetic field on the Romanian territory, such as (1) the presence of a component related to the solar 11-year cycle ("the 11-year variation") in repeat station data, (2) modeling the magnetic structure of the lithosphere using the horizontal component of the field for the time interval 1980-2004, (3) determining the geographical distribution of the secular variation (isopore maps) for the intervals 1969-1978 and 1978-1991 and of maps regarding the secular variation impulses at 1978.0 and 1991.0 epochs.

At present the problem of unitary treatment of the entire volume of accumulated data in the preceding period. The beginning was made within the frame of the contract IDEI no. 151/2007, in which all measurements of the horizontal component carried out between 1965-2000 by means of the two QHM magnetometers were processed in a uniform way, using computer codes written in the preceding contracts. In the current stage, this approach has been continued by recalculating all calibration measurements taken at the Surlari Geomagnetic Observatory before and after the field campaigns.

In *Chapter 2*, entitled "**New magneto-telluric and geomagnetic measurements in Romania**," geomagnetic measurements taken in November at 4 repeat stations of the

National Secular Variation Network, namely Costesti, Provita, Mizil, Tonea, and at the Surlari Geomagnetic Observatory are reported.Measurements were taken by me3ans of a DIFlux Lemi-024 theodolite (magnetic declination and inclination), of a Geometrics-856 proton magnetometer (the total field F), and of two QHM quartz magnetometers (the horizontal component H). Also, in parallel, recordings of the geomagnetic field components (X, Y, Z) were take by means of a Lemi-018 fluxgate magnetometer. Results of the preliminary processing will be used in later stage of the contract.

In *Chapter 3*, entitled “**Review of magneto-telluric data for Romania,**” the data bank of the Institute of Geodynamics regarding magneto-telluric measurements and results is presented.

The study of the electric properties of lithosphere on the Romanian territory has been performed by deep magneto-telluric soundings, along 18 geo-transects. As one of the main objectives of the study was to derive the distribution of the electrical conductivity in Romania, all major tectonic units were sampled.

Also, to study the active seismic zone Vrancea and neighboring areas, low-frequency electromagnetic soundings were carried out, along geo-traverses that took account of the terrain morphology, covering both the active seismic area and the neighboring ones and observing the condition of perpendicularity to the major geological structures. That way both the existing tectonic relationship and their possible evolution could be established. Equally important were also the number of soundings along a profile and the duration of recordings, as time series capable of giving reliable information on the spatial distribution of electric conductivity/resistivity at lithospheric levels (pseudo-section, 2D model) were needed.

For a geo-traverse of magneto-telluric soundings, the structure of the data base appears as:

Profile code/ year	Endcoordinates				No. SMT	Spatial distribution					
						Pseudosection				2D Model	
	Lat.	Long.	Lat	Long.		ρ_{xy}	ρ_{yx}	φ_{xy}	φ_{yx}	2D Images compilated from the 1D inversion	2D Modeling Tomographic images
A/2001	43^{o}42”	28^{o} 25”	44^{o} 12”	28^{o} 48”	34	1	1	1	1	34	1

The electromagnetic data base has the form:

Year	Profile code	Sounding code	Coordinates		Distribution type as a function of T				Model of inversion	
			Lat.	Long	ρ_{xy}	ρ_{yx}	φ_{xy}	φ_{yx}	1D	Layers no.
2002	**A**	10	47°30'00''	26°00'00''	1	1	1	1	Method: Marquardt	6

with ρ_{xy} and ρ_{yx} are resistivities, φ_{xy} and φ_{yx} are phases, and T is the period in seconds.

In the detailed scientific report several representative resistivity and phase curves are shown, both for the seismo-active Vrancea area and for the main tectonic units.

In *Chapter 4*, entitled "**Review of CME, HSS, and geomagnetic indices**", the main information regarding the coronal mass ejections, the heliospheric high-speed streams and the geomagnetic activity is presented.

The *coronal mass ejections (CME)* are huge quantities of magnetized plasma ejected from the solar corona into the interplanetary space. CMEs observed in the interplanetary space are also called *interplanetary coronal mass ejections (ICME).* Generally the latter are detected as a result of characteristic signatures: abrupt increase of speed, increase of the magnetic field, rotation of the magnetic field, decrease of electron density and temperature etc. When these ICMEs interact with the terrestrial magnetosphere, major geomagnetic disturbances, called geomagnetic storms, may occur. The geomagnetic storms are characterized by significant variations of the geomagnetic indices : aa, Dst, AE, supplied by the World Data Center at Kyoto. Storms are classified as minor (-30 nT>Dst>-50 nT), moderate (50>Dst>-100), major (-100>Dst>-150 nT), and severe (Dst<-150 nT).

Among morphologic, kinematic and physical properties of CMEs we mention:

- *Position angle:* is the angle with respect to the north of the Sun, measured counter clockwise, at which a CME is seen in images provided by coronagraphs (LASCO on SOHO, COR on STEREO etc.) A systematic variation of this angle with the solar cycle was observed: during the minimum of the solar activity the CMEs tend to occur in the vicinity of the solar equator, but in the ascendant phase they can be also observed in the polar zone.
- *Angular width:* (measured from the Sun's center). The smallest CMEs angular width (37 deg.) is measured by the terrestrial coronagraph MK3 from the Mauna Loa solar observatory. The largest mean angular width (72 deg.) is given by observations made by the LASCO coronagraph from the space mission SOHO, probably because the higher resolution of LASCO allows detection of CMEs originating at the center of the solar disc that have larger apparent widths.

- *Speed*: the CMEs speed vary between less than 100 km/s to higher than 2000 km/s, with mean values of 400-500 km/s. They vary during a solar cycle, the smallest average values for CMEs observed by LASCO being recorded during the minimum of solar activity.
- *Acceleration*: the CMEs associated with solar eruptions are more accelerated than other CMEs. From this observation, the existence of two CME types was suggested: those associated with solar eruptions, that start with high speed being later decelerated and those associated with eruptive prominences, gradually accelerated.
- *Mass*: CME mass vary around a mean value of 1.7-4.7 10^{15} grams.. It is generally underestimated, because it is measured in 2D images, with errors related to the projection.
- *Energies*: the kinetic and potential energies of the CMEs can be derived from the measured mass and speed, underestimated because of imposed limitations. The total mechanical energy of a CME is of the order of 1031-1032 erg, with potential energy dominating the so-called flux rope CMEs (they are associated with an eruptive prominence). In general, the magnetic energy of a CME is the dominant factor.
- *Source*: CMEs may have various sources, such as solar flares, eruptive prominences, instabilities at the base of coronal currents, dimming, EIT waves etc.

Since 2006, when the STEREO mission was launched, observation of CMEs from various view angles has been possible. As a consequence the 3D structure, the real direction of propagation and the real speed of these phenomena could be determined. Reconstruction techniques such as triangulation, polarization ratio, direct modeling have been suggested, Dr. Marilena Mierla, a participant in the contract, having an important role in devising them. Continuous monitoring of CMEs resulted in on-line catalogues. A complete list of CMEs observed by LASCO/SOHO can be find at http://cdaw.gsfc.nasa.gov/CME list and a list of halo CMEs at http://cdaw.gsfc.nasa.gov/CME_list/halo/halo.html. Before the SOHO era, the catalogue “A Revised and Expanded Catalogue of Mass Ejections Observed by the Solar Maximum Mission Coronagraph” by JT Burkepile, OC StCyr, HAO, NCAR< Boulder, Colorado, 1933 was available.

To conclude, we mention that the web page of the project has been initiated. The report can be found at http://www.geodin.ro/IDEI2011/engl/index.html.

Project Director,

Dr. Crisan Demetrescu

Corresponding member of the Romanian Academy