SEISMOELECTROMAGNETIC RESEARCH IN THE FRONTAL PART OF THE HELLENIC ARC: RESULTS AND EXPECTATIONS.

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ABSTRACT

In the present work we report the results of the seismoelectromagnetic research in VLF and ULF frequencies,as well as our expectation for the future development in the frontal part of the Hellenic Arc. To explain the ULF observations, a model based on the Motion of Charged edge Dislocations (MCD) is introduced. The feasibility and efficiency of the MCD concept is demonstrated. Furthermore the SUPRE project and the GAVDOS proposal are presented. GAVDOS is concerned with the installation of a Interdisciplinary Research Observatory in the isle of Gavdos, the Southernmost point of Europe, a collision area between African and Aegean plates.

INTRODUCTION

During the last decade the Technological Educational Institute of Crete, began developing a Geophysical and Geohazards laboratory in its territory (Hellenic Arc). Off the arc to the west and south the Hellenic trench exists, which is the front of the collision between the African and the Aegean plates. The crust below Crete is continental with thickness ~32km, but it reaches a minimum (~18km) in the Cretan Sea. Southern of Crete the crust becomes oceanic and its thickness decreases up to ~16km at the Hellenic trench. This location of Crete is the main reason for their complicated geological structure, the high tectonic rates, which becomes apparent by large active faults, and the significant shallow and intermediate-depth seismicity of the broader area of the islands. One of the principal directions of the research is to support theoretical, field and laboratory experiments in order to understand the physics of earthquake focus which is hidden on the seismoelectromagnetic phenomena. In this presentation we report the results of this research as well as our expectation for the future development of seismoelectromagnetic research in the frontal part of the Hellenic Arc.

A NETWORK FOR THE OBSERVATION OF SEISMOELECTROMAGNETIC EFFECTS.

A network for the study of naturally occurring electromagnetic activity has developed. The system records the earth's electromagnetic field variations in stations installed along Crete island [1,2]. In each field station, we measure, the electromagnetic field variations, in VLF frequencies (i.e in 3 and 10 kHz). Furthermore in particular stations earth's electric field as well as atmospheric HF one (in 41 and 53 MHz) is measured [3, 4]. The experimental results indicate the presence of electromagnetic variations in VLF and HF range associated to shallow and intermediate depth earthquakes in the southern part of the Hellenic Arc, in the vicinity of Crete island (Greece) [5]. The results indicate that electromagnetic variations appear to follow an invariant time pattern [6,7]. The latter needs a theoretical explanation and a robust laboratory demonstration.

ARTIFICIAL INTELLIGENCE AND NEURAL NETWORKS TECHNIQUES FOR THE RECOGNITION OR THE BETTER IDENTIFICATION OF SESIMOELECTROMAGNETIC SIGNAL.

Since the recognition of a seismoelectromagnetic anomaly is mainly based on empirical way, we consider a recognition approach using an Artificial Intelligence and Neural network techniques [8]. Using the concept of mutual information a method for the recognition of a possible anomaly using data in VLF range from a network of four stations distributed along Crete was developed [9]. As regards the earth's electric field preseismic anomaly, which is aggravated by magnetotelluric disturbances, a Dynamic Neural Network (DNN) structure is used to predict the behaviour of the time series of the field which induced within the earth by external ionospheric sources. In order to improve the performance of the prediction we introduce a structure that includes two DNNs, with synaptic weights centred at two different points. However, only the DNN which corresponds to the minimum error signal is active at a time. In this way we can achieve

less prediction error. Using the aforementioned neural network we lead to a better identification of any possible preseismic anomaly [10, 11]

A THEORETICAL MODELS FOR THE GENERATION OF ULF ELECTRIC PRECURSORS.

A number of recent laboratory experiments have detected the electromagnetic emission prior to brittle failure of rock specimens under stress [12, 13]. Such observations indicate that the processes of crack formation /propagation may be accompanied by spontaneous generation of electrical polarisation (electrification). To explain the observations,a model based on the Motion of Charged edge Dislocations (MCD) is introduced [14, 15, 16, 17]. Considering that crack formation amounts to non-elastic deformation, we present a model for the generation of electric current in rocks under stress, involving the strain rate, which is influenced by the MCD process and demonstrate the relationship between current density and strain rate. The feasibility and efficiency of the MCD concept is demonstrated. The necessary stress rate can be estimated theoretically and compares well with laboratory data. However, field strength is heavily dependent on dislocation density (i.e. on the mechanical and thermal history of the material as well as its present state) and bulk resistivity. The latter is a crucial factor because it turns out that MCD is more efficient in unsaturated or dry rock and the MCD may be suppressed by the presence of saline fluids. Using this mechanism and the geometrical characteristics of the MCD source we simulate the propagation of the electric and magnetic fields and their 'received' characteristics as a function of the source-receiver separation. The simulation as well, demonstrates the feasibility of intermediate - long-distance electric precursor to earthquakes. The brittle failure as a critical point process in a self-organised system, may impose constrains on the expected amplitude of the electric earthquake precursors. These assume the form of a fractal scaling law which is constructed from first principles and relates the observed amplitude, through the size of the electrified rock volume to the magnitude of the upcoming earthquake : $E=C_sM^b$ with $b\approx0.35$ and C_s dependent on the specific properties of the source the source-receiver path. The MCD model has been applied to the analysis of a number of electric signals reported to precede large earthquakes in the area of Greece and successfully reproduced their temporal and spatial characteristics [18, 19, 20]. Emphasis in given to the fact that the spatial characteristics of the observed signals could be reproduced with buried electric dipole configurations closely related to the focal mechanism solutions of the respective earthquakes. Observations of ULF electromagnetic emissions possibly associated with large earthquakes have been presented and discussed in a number of recent publications [21, 22]. These investigations concluded that prior to the earthquakes analysed therein, there has been a significant increase of the intensity of the vertical magnetic field component, and, there has been an evolutionary behaviour of the ULF power spectra assuming the form of an inverse power-law with the exponent ß decreasing towards unity. An explanation of these observations in the frame of MCD model is given, by assuming that the ULF emissions are due to some precursory, time dependent polarisation, appearing in an ensemble of spherical volumes embedded in a conductive half-space and distributed according to a fractal power law. According to this model we calculate the resulting transient magnetic field, which turns out to be mainly vertical and observable only if the seismogenic process generates a source with polarisation rate perpendicular to the vertical plane through the source and the receiver. In order to explain the 1/f behaviour, we assume that the evolution of the precursory polarisation process is not coherent throughout the excited ensemble, (i.e. there's no unique relaxation time), but rather that the sources emit quasi-incoherently, exhibiting a spectrum of relaxation times having energy dependence expressed by an Arrhenius law with distributed energies. We show that the macroscopic ULF field resulting from the superposition of such an ensemble of sources has power spectrum distributed according to an inverse power-law and we discuss the conditions under which, such a power spectrum evolves towards an 1/f behaviour. It appears, therefore, that the MCD model albeit preliminary is self-consistent and based on physically plausible principles and may be developed to a working theory of ELF-ULF earthquake precursors

THE SUPRE PROJECT IN RELATION TO STUDY OF THE ULF ELECTROMAGNETIC PHENOMENA RELATED TO EARTHQUAKES

The SUPRE project strengthens collaboration and co-operation of the research groups from Greece, Italy, Russia, Ukraine, Georgia and combines their expertise in study of the ULF-electromagnetic processes of space and lithospheric origin and in tracing earthquake precursory signatures by means of the ULF measurements carried out at seismically active regions. The test regions for the SUPRE project are the following areas: the South front of the Hellenic arc, Crete Island, Greece, the South Apennines chain, Italy and the middle part of Caucasus mountain chain, Republic of Georgia. In the frame of SUPRE project the following topics are studied [23] a) development of an advanced ULF measurement technique and construction of the appropriate instrumentation for field experiments in the proposed seismically active regions, b) synchronous observations of the ULF electromagnetic and seismic signals at seismically active regions to investigate evolutionary processes and extreme events (short-time critical physical processes) related to earthquake preparation and energy release [24,25], c) development of mathematical methods for analysis of the geophysical time

series on the basis of traditional approaches (magnetotelluric methods, parametric, local and global autoregressive ones) and contemporary methods (fractal, multifractal, multifactor analysis, modern information techniques) leading to disclose precursory signatures d) development of theory and numerical modelling methods for geophysical diffraction tomography with application to the unite seismo-electromagnetic tomography experiment in the dominant field conditions of the seismically active areas e) simulation of the physical processes in seismoactive regions on the basis of SOC (self-organised criticality) consideration and of the theory of fracturing and crack dynamics [26].

QUO VADEMUS? GAVDOS: THE INTERDISCIPLINARY RESEARCH OBSERVATORY OF SOUTHERNMOST EUROPE,

International collaboration is necessary to monitor, verify, integrate, and finally supply diverse and long-term data needed to understand global phenomena and geosphere processes. This proposal is concerned with the installation of a Interdisciplinary Research Observatory in the isle of Gavdos, the Southernmost point of Europe, an area of collision of African plate with the Aegean one. This network of stations will integrate the existing research facilities not only in Europe but also in Middle East and Russia as well, in order to study the Lithosphere-Atmosphere-Ionosphere Coupling. The installation of the appropriate equipment in the isle of Gavdos will provide constrains on the physical properties of long term and transient coupling of lithospheric, atmoespheric and ionospheric physical parameters. To develop an integrated global observing system, by combining research and observations (on the surface and the space), we need to connect the results from physical parameters as long as possible. To this direction the operation of GAVDOS will meet scientific community increasing demand for the collection of multidisciplinary data to reach deeper understanding of large-scale phenomena (such as geodynamic, atmosheric and ionospheric processes). The primary objective of this project is to determine consistently and reliably : (1) the lithospheric activity, (2) the upper atmosheric and ionospheric parameters and (3) to carry out long term geophysical observations in the area. As a consequence it will improve the international reference ionospheric model and will also determine the earths tectonic deformation field in the region of Crete, Greece.

AS A CONCLUSION.

Earthquake processes (i.e., the “truth”) are complex one and occur at time scales and places completely indifferent to the plans and requirements of our science. On the other hand sesimoelectromagnetism is science in the making. Thus it is clear that “Truth is much too complicated to allow anything but approximations” (John Von Neamann) and in order to obtain the right one we need more and high quality observations, improved theories, well controlled laboratory experiments and a lot of passion!!

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