EFFECTS OF SYNCHRONIZATION BETWEEN ULTRA LOW FREQUENCY GEOMAGNETIC COMPONENTS VARIATIONS AND SEISMIC NOISE

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ABSTRACT

We analyze a series of data in the ultra-low frequency (ULF) range of geomagnetic variations, which are collected from search coil instrument and acquisition system at Panagyuriste, Geomagnetic Observatory (PAG), Bulgaria, a part of South European Geomagnetic Array (SEGMA, http://sole-terra.aquila.infn.it/it/), and data for seismic noise collected at three Bulgarian seismic stations (VTS, RZN and KDZ part of National Operative Telemetric System for Seismological Information) and three Turkish seismic stations (GOM, KULA and ALAN, https://www.orfeus-eu.org). The analyzed time period begins at 01 December 2019 and lasts till 31 January 2020.

DFA (detrended fluctuation analysis) scaling characteristics for two different time scales (10 – 180 sec. and 10 – 900 sec.), Hurst exponent and the coherence of the geomagnetic and seismic signals are determined and discussed. Wavelet analysis is applied to calculate and identify the dynamical behavior of the coherence of the width of singularity spectrum and of Hurst exponent for the vertical seismic components and the three geomagnetic components variations. We observe an unusual behavior in all investigated parameters, which appears since the 22-nd of December 2019 till the end of January 2020 and two other periods (22-24 December 2019 and 10-12 January 2020) with unusual low levels for DFA exponent which appears for the vertical (Z) component of the geomagnetic field variations.

Based on the results obtained, we assume that such behavior of the studied parameters is not accidental and are most probably related to natural phenomena.

Keywords: ULF, geomagnetic variations, seismic noise, synchronization

INTRODUCTION

Understanding the relationship between the parameters of different geophysical fields and the seismic noise is still an open question nowadays. Various cases of unusual behavior at groundwater level [1], radon emissions, change in the total electron content [2] in ionosphere over the seismic zones and atmospheric anomalies [3], electromagnetic anomalies, etc. have been described in the scientific literature. Many authors [4] has studied the possible connection between Earth's magnetic field in different frequency

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Indexing of ULF/ELF electromagnetic emissions as a health and life quality factor

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Summary

The authors of the presented work aim to present a project for future work in the field of electromagnetic geophysical methods for applying ULF/ELF electromagnetic emissions measurements as a health and life quality factor.
The sources of ULF and ELF are various and could be classified as outer and internal in respect the place of generation. The outer, generally, are geomagnetic pulsations, the Schuman resonance, thunderbird activities having at all global character. The outer sources are due to natural magneto telluric currents generated in globe core, or a product of artificial radar work of humans reaching tens of MW of power. The level of ULF and ELF variations is an important parameter that directly influences the live cells metabolism.
The expected results are:
Development of indexing methodology of the ULF/ELF variation
Comparison between the traditional indexations and the proposed one
Elaboration of a practical evaluation scale having direct impact on the human's health and the live quality
Development of a measuring system for extending existing one
Informing the public with adequate information as a media announces, workshop etc. about the nature, the benefits and the level of damage caused by these radiation, especially of the ULF/ELF diapason.

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Immersed nano-sized Al dispersoids in an Al matrix: effects on the structural and mechanical properties by molecular dynamics simulations

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Abstract

We used molecular dynamics simulations based on a potential model, in analogy to the tight binding scheme in the second moment approximation, to simulate the effects of aluminium icosahedral grains (dispersoids) on the structure and the mechanical properties of an aluminium matrix. First we validated our model by calculating several thermodynamic properties referring to the bulk Al case and we found good agreement with available experimental and theoretical data. Afterwards, we simulated Al systems containing Al clusters of various sizes. We found that the structure of the Al matrix is affected by the presence of the dispersoids resulting in well ordered domains of different symmetries that were identified using suitable Voronoi analysis. In addition, we found that the increase of the grain size has a negative effect on the mechanical properties of the nanocomposite as manifested by the lowering of the calculated bulk moduli. The obtained results are in line with available experimental data.

1. Introduction

Nanostructuring is usually used to improve the mechanical properties of bulk (coarse-grained) metals and alloys. In this context, structures in the nanometre range as precipitates, different phases or dislocations arrays are introduced into the materials. The reduction of grain size down to the nanometre regime has opened new and fascinating avenues for research in several aspects of materials science. Nanocrystalline materials are believed to exhibit quite different responses under irradiation environments compared to coarser-grained materials. From a

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SYNCHRONIZATION OF MICRO-SEISMIC NOISE AND ITS STATISTICAL PARAMETERS BEFORE RIDGECREST EARTHQUAKE M7.1 ON 6-TH OF JULY 2019

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ABSTRACT

We analyze the micro-seismic noise recorded at five seismic stations – DEC, DJJ, FMP, MWC and RPV. They operate within CI: Southern California Seismic Network

(SCSN), USA. The data set is collected from 01 July 2018 till 31 July 2019 and all seismic events with a magnitude Mw≤4 are excluded.

Our main goal is to find the effects of seismic noise synchronization between different seismic stations using data relevant to the vertical seismic components.

The width of the multifractal spectrum, the spectral exponent and Hurst exponent are determined, analyzed and discussed. About 150 days before Ridgecrest earthquake M7.1, the onset of low-frequency synchronization between all analyzed seismic stations is observed, rising to high frequencies as the earthquake approaches. Also a stable level of increasing coherence is observed which begins 70 days before the earthquake happened and remains at a relatively high level until the earthquake. There is an unusual and extremely increasing of Hurst and the spectral exponents 50 days before the earthquake.

Our study is an independent confirmation of scientific results obtained by other authors.
Keywords: earthquake, multifractal spectrum, coherence, seismic network

INTRODUCTION

This article is aimed at finding and investigating periodic oscillations and synchronization effects in seismic records occurring before earthquakes. A prerequisite for such studies is the assumption that in the metastable lithosphere, immediately before earthquakes, its own periodic oscillations occurs or they are "selectively" amplified by external sources, furthermore, a collective behavior of the microseismic field begins. [1, 2, 11].

In order to find the effects of field synchronization, the measure of record coherence was initially evaluated after transitioning to 30 seconds sampling (after averaging 1200 times the output at a sampling rate of 40 Hz) in a relatively small time window of 28 days. The transition from the output microseismisms to the study of parameter variation

LOCAL SPECTRAL CHARACTHERISTICS OF ULTRA LOW FREQUENCY GEOMAGNETIC VARIATIONS WITH MODERATE GEOMAGNETIC ACTIVITY CONDITIONS AT MID LATITUDES

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ABSTRACT

The study of the dynamic behavior of the Earth's magnetic field and its interaction with the Solar wind is an important for better understanding of the processes in the magnetosphere and on the surface of the Earth's ground. This dynamic system is created due to solar-terrestrial interactions. The effects on the variations of the magnetic field induced by geomagnetic storms are strongly dependent on the local time and the latitude.

Our goal is to study of the spectral characteristics of the ULF geomagnetic field variations with moderate geomagnetic activity conditions. The data sets for the ULF geomagnetic field variations, recorded at Geomagnetic Observatory Panagjuriste, Bulgaria, for the Bz component of the IMF (Interplanetary Magnetic Field) and for the Kp index value are analyzed. Applying Morlet wavelet analysis over time intervals with duration of four hours, the dynamic spectra of the geomagnetic field variations were obtained for three days: 16 July 2017, 31 August 2017 and 20 April 2018.

Original results of the geomagnetic field variations over different time scales are obtained. These are disturbed by moderate geomagnetic activity over all time scales. The disturbances are compared by the time of their occurrence and periods of manifestation.

It is found that all disturbances behave in a similar way along the three days. The geomagnetic variations over time scales 150-700 seconds (in Pc5 range) are strongly affected by the geomagnetic storms. They are related with energy transfer from the solar wind to the magnetosphere and many factors connected with magnetosphere-ionosphere system interactions.

For time scales smaller than 150 seconds (in Pc2-Pc4 range) these type of disturbances in the ULF geomagnetic field variations behave differently on 31 August 2017 for the time intervals 00-03UT, 12-15UT and 20-23UT, where in contrast to the same intervals of the other days, they appear predominantly with time scales smaller than 150 seconds: 10-45 seconds, 45-150 seconds and 25-75 seconds.

Keywords: ULF geomagnetic variations, moderate geomagnetic activity, Wavelet analysis

ULTRA-LOW FREQUENCY GEOMAGNETIC PULSATIONS OBSERVED AT MID LATITUDES IN PANAGJURISTE, BULGARIA

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ABSTRACT

The spectral characteristics of the ULF waves (1mHz -1Hz) provide useful information about the conditions in the solar wind and in the magnetosphere.

A series of geomagnetic field variations data are collected by the tri-axial search-coil instrument and acquisition system located at Panagjuriste, Geomagnetic Observatory (PAG), Bulgaria and other series of data are collected from two different instruments located at Conrad Observatory (WIC), Austria and Ebro Observatory (EBR), Spain, which operate within INTERMAGNET - the global network of geomagnetic observatories.

We analyze the time series corresponding to the period 00 - 01 UT (02-03 LT) on 29 December 2020. To determine the spectral characteristics of observed geomagnetic pulsations, we apply the autocorrelation analysis to obtain the autocorrelation function and the power spectra, as well as Morlet wavelet analysis of the considered time series.

Pulsations with an amplitude modulation period of about 15 min. (~900 s.) and main periods at 84, 75 and 68 seconds are determined. The specific spectral characteristics of these pulsations are obtained on the basis of the Morlet dynamic spectra. They show continuous ULF pulsations represented in four wave "packets" of sinusoidal oscillations with varying periods from 30 seconds till 115 seconds and main periods at 84 s., 75 s. and 68 seconds.

We conclude that the recorded pulsations at Geomagnetic Observatory Panagjuriste, Bulgaria, located at mid latitudes, on 29 December 2020 during the time interval 00-01 UT are continuous ULF pulsations within the range Pc4 (45-150 seconds). Similar ULF continuous pulsations in the Pc4 range, with similar power spectra during the same time are observed both at Ebro and Conrad Observatories.

Keywords: ULF, pulsations, geomagnetic field, Panagjuriste

INTRODUCTION

The solar wind and processes in the Earth's magnetosphere due to external and internal sources produce ULF (ultra-low frequency) waves in the frequency band ~1 mHz to ~ 1Hz, which can be recorded in the magnetosphere and on the ground as continuous pulsations (Pc) and irregular pulsations (Pi). These waves were reported for the first time in 1757. So far these complex phenomena have extensively investigated [1].

ULF waves originate in different regions of the magnetosphere and they differ by their associated periods, polarization structure, waveforms, spatial structure, etc. Investigation

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Scaling Characteristics of SEGMA Magnetic Field Data around the Mw 6.3 Aquila Earthquake

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A b s t r a c t

We apply detrended fluctuation analysis (DFA) on fluxgate and search-coil data in ULF range (scales 10-90 s or 0.1-0.011 Hz) for the months January-April 2009 available from the South European GeoMagnetic Array stations: Castello Tesino (CST), Ranchio (RNC), and L'Aquila (AQU) in Italy; Nagycenk (NCK) in Hungary; and Panagyuriste (PAG) in Bulgaria. DFA is a data processing method that allows for the detection of scaling behaviors in observational time series even in the presence of non-stationarities. The *H* and *Z* magnetic field components at night hours (00-03 UT, 01-04 LT) and their variations at the stations CST, AQU, NCK, and PAG have been examined and their scaling characteristics are analyzed depending on geomagnetic and local conditions. As expected, the scaling exponents are found to increase when the *Kp* index increases, indicating a good correlation with geomagnetic activity. The scaling exponent reveals also local changes (at L'Aquila), which include an increase for the *Z* (vertical) component, followed by a considerable decrease for the *X* (horizontal) component in the midst of February 2009. Attempts are made to explain this unique feature with artificial and/or natural sources including the enhanced earthquake activity in the months January-April 2009 at the L'Aquila district.

Key words: detrended fluctuation analysis (DFA), magnetic field data, ultra low frequency (ULF), pulse activity, polarization, earthquake.

EARTHQUAKE EFFECTS RECORDED ON MAGNETOGRAM - WHERE, WHEN AND WHY

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ABSTRACT

Records of the magnetometers responding to the effects of big earthquakes were noticed more than a hundred years ago. Even then began to dispute what caused these effects: mechanical vibrations of instruments or electric or magnetic oscillations generated by the earthquakes. In Panagjurishte (PAG) observatory we have great opportunity to shed light on this issue because we have four important instruments installed on the site - three different types of magnetometers and one seismometer.

Three large earthquakes with magnitude M_w >6 happened recently in the Balkan Peninsula. These are the events of: 30 October 2020 with moment magnitude M_w 6.9 located in the offshore region north of Samos Island, Greece; 29 December 2020 M_w 6.2 earthquake occurred in Petrinja (Croatia) and 3 March 2021 M_w 6.3 earthquake which hit the northeastern part of the Thessaly basin (Greece). The energy released was enough to give us data for investigation.

In our research we compare the recorded signals of all instruments. It is shown that a magnetic torque is introduced by the pendulum swing of the FGE suspended sensors. This instrument may in fact be used in some places as a seismometer of ultra-low sensitivity. But even though we expected to find some small amplitude signals from real electromagnetic waves generated by the earthquakes. It doesn't happen however either because these effects were too small to be observed against the background of geomagnetic noise or they are really missing due to the great distance from the epicenters or the electrical properties of the earth section under the site.

Keywords: earthquakes, magnetic records, noise identification, raw data, PAG observatory

INTRODUCTION

Continuous magnetic records which are performed in geomagnetic observatories contain the signals from the Earth's magnetic field but also very often there is noise, which is result of some sources not associated with natural variations of that phenomenon. Sometimes the digital data show "mysterious" errors, which are not easy to detect and correct without an independent source These could be due to electronic failure or artificial man made origin. In addition, however, in practice of observatory measurements, a presence of seismomagnetic effect is also possible, when we observe oscillations in the magnetometer's data. These oscillations arise when a seismic wave

Effects of a strong thunderstorm on the ULF geomagnetic field variations

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SUMMARY

On 24 May 2018, a severe thunderstorm, bringing rain and hail, occurred at Panagjurishte Geomagnetic Observatory, Bulgaria, lasted for a few hours.
The data sets of geomagnetic field variations in ULF range, recorded by the acquisition system of tri-axial induction magnetometer sampled at 1 Hz are analyzed and the results are discussed. Morlet wavelet analysis over time scales 1-2000 s for the X (north-south direction), Y (east-west direction) and Z (down direction) components is performed. The Power spectra for the few hours before and after the beginning of the thunderstorm along the Z component are obtained. They mark powerful disturbances during and after the storm with periodicity in time scales 500-1350 s.
It is found that the influence of the strong thunderstorm on the geomagnetic variations along the three directions is significant. The time behavior of the three geomagnetic components shows that the strong lightning at 10:25 UT affects the absolute value of the Z component, unlike X and Y components values over fifteen hours. The induced voltage by the atmospheric electric current system in the Z component is about 5 Volt.

Pc5 PULSATIONS OBSERVED DURING THE GEOMAGNETIC STORM ON 12 MAY 2021

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ABSTRACT

The study of ultra-low frequency (ULF) waves and geomagnetic pulsations plays an important role in better understanding the mechanisms of their generation and spread in the magnetosphere and on the ground. The magnetospheric ULF waves, which provide useful information about the conditions in the solar wind and in the magnetosphere, can be detected on the ground by different types of magnetometers and recorded as geomagnetic pulsations – continuous and irregular. This paper aims to study the characteristics of Pc5 geomagnetic continuous pulsations recorded at mid latitudes during the strong geomagnetic storm ($Kp = 7$) that occurred on May 12, 2021. The sets of time series of data at sampling period 1s, recorded along the three geomagnetic directions (X, Y and Z), are shown and analyzed. A spectral analysis, based on the Morlet Wavelet transform, is applied. It shows powerful geomagnetic disturbances in the Pc5 band (1.7-6.7 mHz) in two time intervals: 00-02 UTC- before the beginning of the storm and 10-15 UTC- during the storm. Furthermore, the Fast Fourier Transform (FFT) band pass filter is applied to the data series, and Pc5 pulsations are shown. It was concluded that their emergence was correlated with the dynamics of changes in the interplanetary magnetic field (IMF) Bz component, solar wind plasma speed, and flow dynamic pressure.

Keywords: ULF, pulsations, geomagnetic storm, Panagjuriste

CHARACTERISTICS OF Pc5 PULSATIONS ACTIVITY AT MID LATITUDES DURING DECEMBER 2019

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ABSTRACT

Magnetospheric pulsations and the mechanisms underlying their generation are topics under active studies. The Pc5 *(f =1.7–6.7 mHz*) geomagnetic continuous pulsations, recorded at mid latitudes *(L =1.6*) during December 2019, with a low level of geomagnetic activity, are analyzed and discussed in this paper. The data sets of the series on geomagnetic field variations recorded at Panagjuriste Geomagnetic Observatory in Bulgaria are analyzed. The spectral characteristics of the pulsations were determined by Continuous Wavelet Analysis (CWT). It is demonstrated that Pc5 pulsation activity appears with all ranges of periods (140-600s) on December 6, 8, and 18, 2019, at time intervals of 02-17 UTC, 14-20 UTC, and 00-16 UTC, respectively. Then, the solar wind (SW) plasma speed, the flow dynamic pressure, and the geomagnetic index *Kp* are computed for every case of recorded Pc5 pulsations. It is suggested that recorded continuous pulsations in the Pc5 range are due to step-like or sudden increases in solar wind oscillations and variations of the flow dynamic pressure, which precede the appearance of pulsations and drive compressional magnetic field variations in the magnetosphere.

Keywords: Pc5 pulsations, geomagnetic field, spectral characteristics

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Nonlinear Analysis of Geomagnetic Variations Data from Panagyuriste Geomagnetic Observatory, Bulgaria

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Summary

We apply the detrended fluctuation analysis (DFA) to the geomagnetic field data set collected from 14 till 31 May 2016 by the equipment at Panagyuriste Observatory, Bulgaria and calculate DFA exponent and its temporal evolution in different time scales (10-180 s, 10-900 s). Performing this analysis we obtain useful information about long range correlations of time series and about the global and the local variations of the geomagnetic field in the ULF range. It is found that an unusual behavior of the DFA exponent is observed only for the vertical (Z) geomagnetic component on 19.05.2016. We assume that this unusual behaviors of the scaling exponent and the fluctuation function in time scale 10-900 s may be due to lithospheric source.

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ЕЛЕКТРОТЕЛУРИЧНИ ИЗМЕРВАНИЯ В ULF ДИАПАЗОНА ЗА ИЗСЛЕДВАНЕ НА КРАТКОСРОЧНИ ПРЕДВЕСТНИЦИ НА ЗЕМЕТРЕСЕНИЯ

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ELECTROTELLURIC MEASUREMENTS IN THE ULF RANGE FOR STUDY OF SHORT-TIME EARTHQUAKE PRECURSORS

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Keywords: electroteluric measurements, earthquake precursors, ULF signals, Earth electric potentials,

Abstract *– An apparatus for monitoring of electrotelluric field variations in the ULF diapason that has been put in operation in seismic station "Krupnik" (SW Bulgaria) is presented. Sensors, measuring scheme, galvanic disconnection solution, and acquisition system integrated in PC are fully considered. Realisation of the principal electronic blocks of the apparatus is depicted. The work is illustrated with data for seismic electric signal (SES) recorded in November 2004.*

Увод

Естествените електрически потенциали и токове в земната кора са следствие на електрохимични и механични процеси, протичащи в нея, и на индуктирани електрически токове от процеси, протичащи в близки до нея области на околоземното пространство. Условно измерваните сигнали могат да бъдат разделени по честотен признак на квазистатични вариации на земния електричен потенциал (ЗЕП) и електрически ULF сигнали, измервани на земната повърхност. За изследване на естествените геофизични полета и телуричните токове в приложната геофизика [1] се прилагат методи на изследване, основани на измерване на потенциалите по земната повърхност и магнитни измервания [2,3,4,5].

Проблеми при конструирането на измервателната система

Методиката на експеримента изисква едновременно измерване на индуцираните в земната повърхност ULF електрически сигнали, ЗЕП и вариациите на земното магнитно поле. При това се измерват диференциално много ниски електрически напрежения от галванични, вкопани в земната повърхност сензори, разнесени на значителни разстояния от измервателната и регистрираща апаратура, които са по-ниски стойности от смущаващите електрически и магнитни полета, породени предимно от антропогенни източници.

За да изпълни основните си функции, в състава на измервателно-регистрираща апаратура трябва да има микропроцесорна система или персонален компютър, необходими за цифроване, визуализация, натрупване, запис и съхранение на данните, от който те периодично да се извличат за обработка и интерпретация. Самият компютър или микропроцесорна система е източник на смущения, съществено по-големи от измерваните сигнали. За измерване на потенциали по земната повърхност, е необходимо измервателната част да няма галванична връзка с компютъра.

Тези комплексни проблеми не могат да се решат чрез стандартни измервателни средства. Това налага създаването на специализиран измервателно-регистриращ комплекс, в който да се реализират всички изисквания [9]

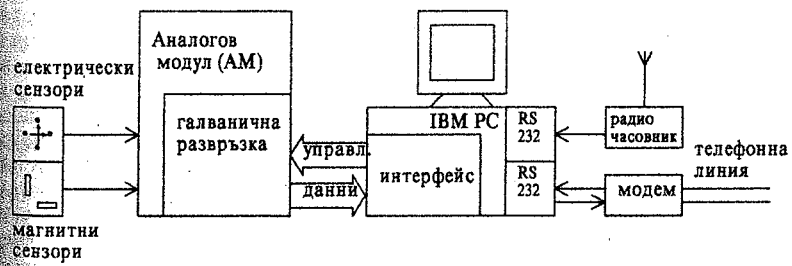
Предлагано решение

Структурата на разработената измервателна система се състои от:

1. Основен компютър, от който чрез модемна връзка през телефонни или радиолинии да се източва периодично информацията, събирана и натрупвана от няколко измервателни комплекса, разположени в предварително избрани пунктове за провеждане на измерванията. В същия компютър се обработва получаваната информация и управлява натрупваната база от данни;

2. *Специализирани измервателно-регистриращи комплекси* (до 16 броя), в които е съсредоточено събирането, начално натрупване, периодично източване и визуализация на събираната информация.

Подобна система може да бъде изпълнена, ако в състава й има специализирана микропроцесорна система или компютър. За разработване на специализирана микропроцесорна система и създаване на програмно обезпечаване за нея е необходимо закупуване на развойна система и програмно усигуряване за избрания микропроцесор. Тези разходи се редуцират, ако ,се използва стандартен персонален компютър, който работи като развойна система на себе си. Разработеният измервателно - регистриращ комплекс се състои от сензори, аналогов модул, и стандартен персонален компютър, при галваническа развръзка между тях. Неговата структурата е представена на фиг. 1.



Фиг. 1. Структура на измервателно-регистриращ комплекс

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SEISMICITY AND MEASUREMENTS OF ELECTROMAGNETIC FORERUNNERS IN THE KRESNA'S EARTHQUAKE ZONE

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Keywords: seismicity, electroteluric measurements, earthquake precursors

Abstract *The earthquake zone of the Kresna-Krupnik region (Bulgaria) is the most dangerous one found in the Balkan peninsula. In 1904 two earthquakes of magnitudes 7.2 and 7.8 have been occurred within 20 minutes interval. The second one was considered as the strongest that struck in the last 200-300 years the continental part of Europe. This earthquake zone is the most active in released seismic energy for the last 15 years, as well. Due to these characteristics the Kresna-Krupnik earthquake zone is an object of active investigations, including electromagnetic ULF continuous measurements of possible forerunners. A specialized measuring system is designed, installed, and set up that works in the seismic station "Krupnik" for more that 2 years.*

The system is aimed toward measurements of geoelectric potentials and ultra-low-frequency electric and magnetic fields, induced by processes both in the magnetosphere-ionosphere and in the lithosphere. The primary goals of these measurements are a study and monitoring of both the natural electromagnetic field variations and the geoelectric potential anomalous changes associated with seimic activity.

Data for the local seismic activity provided by NOTSSI, GPhI are collected. The seismic information for all registered local earthquakes is processed statistically in several parameters – spatial distribution, magnitude, depth and earthquake moments. The information of electromagnetic field measurements is included in order to look for possible relationships between the seismic events and the dynamical variations in the electromagnetic field characteristics – frequency spectrum, amplitude, etc. The goal is to answer to the main question: is there an earthquake electromagnetic forerunners and how we can register them.

Introduction

Earthquake events occurred in the Kresna-Krupnik area (South_West Bulgaria) and their characteristics are under study in this paper. The time interval under consideration is from the beginning of 2004, when the first regular measurements of the ultra low frequency (ULF) electro-magnetic variations have been put. Among earthquakes in this region of 1 by 1 geographical degrees, the strongest ones, with M=7.2 and 7.8 within interval of only 20 min have been occurred on April 4, 1904. Those events have been caused macro seismic effects in the epicentral area, reaching X-th degree on the MSK. The quakes have been followed by the whole spectrum of secondary events, that is typical for earthquakes of that magnitude [1]. The second earthquake (of M7.8) appears as the strongest tremor in the continental Europe in the last 200-300 years. The same region, known as Kresna-Krupnik area even today releases the highest level of seismic energy in Bulgaria [2]. These are the main factors that have directed us in our selection for the investigation of possible electro-magnetic precursors. Over 700 week earthquakes have occurred in last few months and they are presented on Fig 1. The registration is done on the NOTSSI network and earthquakes within magnitude interval M < 1.0 up to M > 3.5 – Fig. 2 are selected. The

APPLICATION OF DFA METHOD TO MAGNETIC FIELD DATA

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Abstract. The detrended fluctuation analysis (DFA) is a method for determining the statistical self-affinity of a signal in stochastic processes and time series analysis. It is very useful in revealing the extent of long-range correlations in time. We apply this method to the analysis of magnetic field data (ULF frequency range) from SEGMA array – a network of magnetic stations geographically located in Italy, Hungary and Bulgaria. We study the behavior of the DFA index, which characterizes the long-range correlations in magnetic field data series over a time period from June 2004 till February 2005. The DFA scaling exponent for each station is computed for two different time scales: 10-180 s and 10-900 s. Our results show both regional trends and local peculiarities of the DFA index. The regional trends are obviously associated with geomagnetic activity (Kp index). The local peculiarities (at a single station) can be produced by multiple sources, may be processes of similar characteristics of limited extent either in the atmosphere/ionosphere system or in the lithosphere.

Keywords: geomagnetic activity, DFA method, SEGMA array.

1. Introduction

Ultra low frequency (ULF) signals may be produced as a result of the interplay of different signals, such as natural signals emanating from solar-terrestrial interaction, lithosphere or artificially generated (industrial noise, disturbances emitted from measurement equipment). In many cases ULF emissions are associated to magnetospheric origin (Masci 2010). To identify the source of ULF emissions associated to the variations of the geomagnetic field different methods (Telesca & Lapenna 2005), such as fractal (Gotoh et al. 1999; Masashi

WHAT WE CAN LEARN FROM THE 2009 M_W 6.3 L'AQUILA EARTHQUAKE

SHORT TITLE: WHAT WE CAN LEARN FROM THE L'AQUILA EARTHQUAKE

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Abstract. This study presents a further analysis of magnetic field pulses in the ULF range data around the 2009 M_W 6.3 L'Aquila earthquake (EQ). Dynamics in the pulse polarization is evidenced and a possible correspondence with seismic anisotropy dynamics is questioned. The polarization of intense pulses observed on 18 March 2009 is interpreted as a short-duration current body beneath the Earth surface, oriented nearly along the main fault/slip of the 2009 L'Aquila EQ. Comparison of variations with characteristic time exceeding 24 hrs applied on local and distant magnetic field data (at L'Aquila and Panagyurishte – Bulgaria, respectively) does not, however, reveal long-duration trends possibly associated with EQ preparation processes.

Keywords: earthquake processes; seismic anisotropy; earthquake precursors; geomagnetic field variations; dichotomous pulses; current-carrying body; lightning activity

1. Introduction

According to the BlackSeaHazNet project under Maria Curie (FP7) program (see http://stardust.inrne.bas.bg/BlackSeaHazNet/), the main purpose is to create

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DFA ANALYSIS OF SEGMA MAGNETIC FIELD DATA AROUND THE M6.3 AQUILA EQ

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Abstract. Recently a preliminary analysis of the magnetic field observations performed at L'Aquila preceding the April 6, 2009 earthquake has been performed (Villante et al, 2010). A possible occurrence of features as i) an increase in the noise background and/or polarization parameter (i.e. the ratio between the amplitude/power of the vertical component and that one of the horizontal component), ii) changing characteristics of the slope of the power spectrum and fractal dimension, and iii) occurrence of short duration pulses have been looked for two years back. It was concluded that the expected ULF disturbances related to earthquakes (if any) are generally weak and sophisticated signal processing methods and a lot of experience are required to evaluate the source of ULF emissions observed at ground. In this report we apply detrended fluctuation analysis (DFA) analysis on fluxgate and search-coil data in ULF range (periods 10-90 sec) for months January-April 2009 available from SEGMA array (Italy, Hungary, Austria and Bulgaria). Remind DFA is a data processing method that allows for the detection of scaling behaviors in observational time series even in the presence of non-stationarities. H and Z magnetic field components at night hours (00-03 UT, 01-04 LT) and their variations at stations AQU, CST, NCK and PAG have been examined and their scaling properties are analyzed depending on geomagnetic and local conditions. As it is expected, the DFA scaling exponents increase when Kp index increases, indicating a good correlation with geomagnetic activity. DFA scaling exponent reveals also local changes –such as a considerable decrease for the H component at AQU station observed in the midst of February. A malfunction of the fluxgate magnetometer at Aquila has been checked up and excluded. Attempts to explain thoroughly this unique feature with artificial and/or natural sources including the

enhanced earthquake activity occurred in months January-April 2009 at Aquila district are made.

Keywords: magnetic field, DFA scaling exponent, fluctuation function, earthquake,

1. Introduction

Magnetic field data and especially those of 1 second resolutions, are well exploited toward searching any seismogenic signatures preceding incoming earthquakes (EQ). Magnetic field variations in the ULF range (0.003-3 Hz) have been studied around series of strong earthquakes and subsequently underwent hot debates about their authenticity and reliability. Performing ULF observations many authors have applied standard and elaborated signal processing methods to magnetic field data to possibly extract seismogenic electromagnetic ULF emission (Fraser-Smith et al., 1990; Molchanov et al., 2002; Kopytenko et al., 2004; Hayakawa et al., 1996; Hayakawa et al., 2007).

In this paper we draw attention to magnetic field data measurements around the Mw6.3 L'Aquila earthquake occurred on 6 April 2009 in Central Italy. Our preliminary results based solely on magnetic field data at L'Aquila observation did not reveal reliable signatures to be associated with the earthquake (see Villante et al, 2010). The only exception was an appearance of intense spikes of ~1 nT magnitude registered 19 days prior to EQ main shock. The next step is to use all SEGMA magnetic field data collected at the five observatories and stations. Remind that the SEGMA observatories are L'Aquila (AQU), Ranchio (RNC), Castello Tesino (CST), in Italy, Nagycenk (NCK), Hungary, Panagyurishte (PAG), Bulgaria which are evaluated in the frame of this work. Stations Ranchio (RNC), Castello Tesino (CST) and Nagycenk (NCK) are equipped with only fluxgate magnetometers developed at the Space Research Institute of the Austrian Academy of Sciences Graz. The observatories L'Aquila, Italy and Panagyurishte, Bulgaria are equipped both with fluxgate and searchcoil magnetometers.

At the beginning the instrumental characteristics of the magnetometers are described. The CHIMAG fluxgate magnetometer was originally developed at the Space Research Institute of the Austrian Academy of Sciences Graz, to investigate magnetic pulsations in the ULF range. The vital parameters of the high temporal resolution 3-axes fluxgate magnetometer are the measurement range of +/- 512 nT, the compensation field of 60000 nT in X and Z and +/- 30000 nT in Y direction. The accuracy is 8 pT at a temporal resolution of 1 Hz, derived from the highest possible sampling frequency of 64 Hz. The 3-axes magnetometer measures in X (positive Northward), Y (positive Eastward) and Z (positive towards the centre of the Earth) direction. The CHIMAG

Geomagnetic disturbances observed at Panagyuriste (PAG) station, Bulgaria on 7-8th of September 2017 during the geomagnetic storm

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Key words: geomagnetic field, geomagnetic pulsations, spectral analysis, Panagyuriste station

Abstract
We report results on the impact of the geomagnetic storm observed on 7-8-th of September 2017 on the geomagnetic field variations in ULF range. We apply FFT filter and spectral analysis on the search-coil geomagnetic data variations (X, Y, Z directions). We obtain the signal distribution at different frequency ranges and dynamical spectra are built. The results reveals that at geomagnetic coordinates 37.02N/ 97.24E and geographic coordinates 42.51N/24.18E the magnitude of pulsations in Pc5 and Pc4 range are more powerful and robust than Pc3, Pc2 and Pc1 range.

Геомагнитни смущения, наблюдавани по време на магнитната буря от 7-8 септември 2017г. в станция Панагюрище (PAG)

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Ключови думи: геомагнитно поле, геомагнитни пулсации, спектрален анализ, станция Панагюрище

Резюме
Докладвани са резултати от влиянието на магнитната буря, наблюдавана на 7-8 септември 2017г. в геомагнитна обсерватория „Панагюрище", върху вариациите на магнитното поле в ULF диапазон. Върху данните за X, Y и Z компонентите, получени от search-coil магнитометър, е приложен FFT филтър и е извършен спектрален анализ. Намерено е разпределението на сигнала в различни честотни интервали и са построени динамичните спектри. Резултатите показват, че на геомагнитни координати 37.02N/ 97.24E и географски координати 42.51N/24.18E, пулсациите в диапазона Pc5-Pc4 са ясно изразени и с много по-голяма мощност от тези в Pc3-Pc1 диапазона.

Introduction

The investigation of different geophysical fields' parameters as a part of system Lithosphere - Atmosphere-Ionosphere is important to study their interactions. Geomagnetic field variations provide useful information on the behavior of other geophysical fields. Many authors (Fraser-Smith, 2009; Karakelian et al., 2002; Parrot et al., 2016; Parrot and Ouzounov, 2011; Villante et al., 2014, 2004) study potential connections between solar activity, magnetospheric - ionospheric disturbances, ocean temperature, anthropogenic noise and lithospheric processes.
Other authors study ULF pulsations and their latitudinal distribution (Bortnik et al., 2007, 2008b; Marin et al., 2014) in particular long period pulsations which were first detected by Stewart (1861) and categorized as Pc5 oscillations by Jacobs et al. (1964). Geomagnetic micropulsations provide useful information about near-Earth plasma and physical/geophysical interaction fields (Chamati et al., 2011; El-Eraki et al., 2014; Roldugin and Roldugin, 2008). Many of the ULF waves and micropulsations seen at the Earth's surface originate outside the magnetosphere: the solar wind, the magnetopause, the ion foreshock, the bow shock and probably the lithosphere. Geomagnetic disturbances/pulsations are not always connected with magnetosphere/ionosphere processes and their origin is a subject of extensive research (Chamati et al., 2009; Nenovski et al., 2013). Studying their spatial distribution, frequency characteristics, polarization characteristics and correlation with phases of storm, the diagnostic of the space conditions and conductivity structure of the Earth may be achieved (McPherron, 2005).
The geomagnetic storm on 7-8th of September 2017 was the strongest in the solar cycle 24 during the solar minimum due to solar flares with unusually high intensity and/or extremely high energy coronal mass ejections (CMEs). It was characterized by two Dst-index minima and can be considered as a sequence of two storms: the first - with Dstmin = −142 nT at 02 UT on September 8th and the second - with Dstmin = −122 nT and at 15 UT on September 8th (Blagoveshchensky and Sergeeva, 2018).
Here we report the results about ULF geomagnetic pulsation and in particular with periods 150-600s (0.002 – 0.007 Hz) and 45-150s (0.007 – 0.022 Hz) observed in the initial phase and during the magnetic storm at the Geomagnetic Observatory Panagyuriste, Bulgaria. The estimated local K-indices are presented in Table 1.

ULF GEOMAGNETIC OBSERVATION AT PANAGJURISHTE, BULGARIA AS A TOOL FOR INVESTIGATION OF THE MAGNETOSPHERE-IONOSPHERE-LITHOSPHERE SYSTEM

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Abstract. A tri-axial search-coil magnetometer system, a part of SEGMA Array (South European Geomagnetic Array), operates since 2003 at the Geomagnetic Observatory Panagjurishte, Bulgaria. It is designated to measure and collect data for the Earth's magnetic field variations, specific geomagnetic events and long-term study of ULF signals. These observations provide information on the dynamical processes in the Earth's magnetosphere, geomagnetic micro-pulsations, fluctuations and storms. Here, we obtained results related to three powerful geomagnetic storms recorded by the search-coil magnetometer during the years 2017-2018. Furthermore, we presented the dynamical spectra in the ULF range of each storm.

Key words: ULF variations, search-coil magnetometer, geomagnetic storm, Panagjurishte.

Introduction

The study of the ULF spectrum (0.001-10 Hz) of the Earth's magnetic field, its local fractal structures, spectral and polarization characteristics are important for the identification of the causes of the associated disturbances. In the last two decades, the analysis of the ULF spectrum of magnetic field is particularly relevant, as it is believed that ULF emissions are likely to be generated directly from the area of preparation of geodynamic processes (Fraser-Smith, 2009; Molchanov et al., 2011). In most of all reported cases of such emissions, recorded by ground-based measurements, these are signals that are not of lithospheric origin, but are related to the interaction of the solar wind with the Earth's magnetosphere. These processes, which have a magnetospheric origin, are recorded on the Earth and together with the ionospheric and local ones, form the electromagnetic

ULF GEOMAGNETIC DISTURBANCES DUE TO MODERATE GEOMAGNETIC STORM AT PANAGJURISTE, BULGARIA

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Abstract. The geomagnetic disturbances caused by the geomagnetic storm on 12 October 2021 – class G1 increasing to G2 are investigated. The data set, recorded at 1s sampling rate at the Geomagnetic Observatory Panagjuriste, Bulgaria, along the X and Y components of the geomagnetic field variations, are analyzed. The time evolution of the ULF variations, the local and the global geomagnetic K-indices and the dynamical spectra in the ULF range are presented. It is found that spectral characteristics before 10 UT along the two geomagnetic components have similarities in term of the time of occurrence, the time scale and power. After 10 UT, the results show radical differences in the manifestations of disturbance in the two geomagnetic components in terms of the time scales in which they occur.

Key words: ULF variations, spectral properties, geomagnetic storm, Panagjuriste.

Introduction

Many parameters that characterize different geophysical fields (Earths magnetosphere, ionosphere, atmosphere and lithosphere) are used and analyzed to identify a possible source of disturbances of ultra-low frequency (ULF) field variations (Chamati and Botev, 2019; McPherron, 2005; Nenovski et al., 2013; Regi et al., 2014; Villante and Vellante, 1998). These variations, recorded by the different types of magnetometers on the ground and in the Space provide very useful information about the Sun and magnetosphere/ionosphere processes (Blagoveshchensky and Sergeeva, 2018; Borovsky, 2020; Chamati, M., 2018). Many centers for scientific information collecting geophysical data include in their database information of ULF observation such as National Geoinfor-

SPECTRAL CHARACTERISTICS IN ULF RANGE OF GEOMAGNETIC STORM OBSERVED AT PANAGJURISTE, BULGARIA ON 27-28 SEPTEMBER 2017

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Abstract. On 27-28 September 2017 at Geomagnetic Observatory Panagjuriste (PAG), Bulgaria the geomagnetic storm - class G2 increasing to G3 was observed. It caused disturbances over the ultra-low frequency (ULF) geomagnetic field variations. The time series of the collected data along the X (north-south), the Y (east-west) and Z (vertical) directions are analyzed. Trough Morlet wavelet analysis the dynamic spectra for the X and the Y components are obtained. They show disturbances strongly corresponding with geomagnetic activity and covers all investigated time scales (1-600s). The two most powerful interferences are recorded on 28 September- 09UTC and 21UTC- along the Y component which strongly correspond with *Kp* index, but not with local *K* index. They don't appear along the other two components. It is found that during the time interval 00-03UTC on 28 September the pulsations are recorded along the X component with periodicity that covers time scales 40-110s and main period about 85s, and they are most likely related to injections of energetic plasma.

Key words: ULF variations, spectral properties, geomagnetic storm, Panagjuriste.

Introduction

The geomagnetic field variations, in particular ULF variations, recorded by the different types of magnetometers provide very useful information about the Sun and magnetosphere/ionosphere processes (Blagoveshchensky and Sergeeva, 2018; Borovsky, 2020; Chamati, M., 2018). Many centers for scientific information collecting geophysical data, such as National Geoinformation Center include in their database information on different geophysical fields (Miloshev et al., 2019) as well as information about geomagnetic field elements (Metodiev and Trifonova, 2020).

INVESTIGATION OF THE ULF GEOMAGNETIC NOISE RECORDED ON MAY 1, 2020 AT PANAGJURISHTE GEOMAGNETIC OBSERVATORY

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Abstract. On May 1st, 2020, at the Geomagnetic Observatory in Panagjurishte, Bulgaria, the unusual ultra-low frequency (ULF) geomagnetic noise was recorded by a tri-axial (X, Y, and Z directions) induction magnetometer. The time series from April 1, 2020 till May 1, 2020 are examined. Applying the detrended fluctuation analysis (DFA), the DFA exponent is calculated for the time series along the three geomagnetic directions, and the results show an unusual decrease in values of the DFA exponent in time scales 10-180s and 10-900s that starts after April 29, 2020. Through Magnitude-Squared Coherence analysis, the correlation and phases between every two geomagnetic components are obtained for the time series on May 1, 2020, under very low geomagnetic activity levels. The high values of the coherence and phase full sync for the X and Z components are observed, in the time period 04:00–20:00 UTC, at a frequency range 0.125-0.25 mHz. The present study does not rule out that the considered disturbances have a lithospheric origin.

Key words: ULF geomagnetic variations, DFA analysis, Magnitude-Squared Coherence, Panagjurishte.

THE GEOMAGNETIC STORM ON NOVEMBER 3-4, 2021: SPECTRAL CHARACTERISTICS IN ULF RANGE AT MID LATITUDES

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DOI:

Abstract. The geomagnetic storm class G3 was recorded on November 3–4, 2021 on the ground-based magnetometers. Using time series of the data corresponding to the horizontal geomagnetic component, the spectral characteristics in the ULF range for the data collected at Panagjurishte (Bulgaria) and Conrad (Austria) observatories are obtained. To obtain the degree of correlation between the X and the Y components at both stations the coherence analysis is used. It was found that the X components have a very high degree of correlation for the entire studied period in the frequency range 0.03125–16 mHz and are fully synchronous in phase. The Y components have significant differences in phase and values of coherence for different frequency ranges. The dynamic spectra depict similar behavior along the X and Y components during the storm. The geomagnetic variations at both observatories were affected at different time scales. The main difference is that the spectral characteristics appear on time scales 200–400s, where disturbances appear simultaneously along the X component at Panagjurishte and along the Y component at Conrad.

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Disturbances in the geomagnetic field recorded on February 6, 2023

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Keywords: geomagnetic field, disturbances, ULF, spectral analysis

Abstract
Data on the variations of the geomagnetic field from three geomagnetic observatories: PAG (Bulgaria), PEG (Greece), and WIC (Austria), along with the solar wind parameters, and the Interplanetary Magnetic Field (Bz) recorded in the period February 5–6, 2023, are analyzed. Through performing spectral and comparison analyses, two types of disturbances are found. The first type manifests itself as an ultra-low-frequency wave (in the spectrum of Pc3–4 pulsations) in the horizontal components of all three stations. It starts at 00:52 UTC and lasts about 25 minutes. It represents a global phenomenon caused by changes in the values of the parameters of the solar wind. The second type occurs locally (at PAG Station) only in the east-west component of the magnetic vector. This is expressed in a smooth increase in its values as well as sharp peaks for the time interval 1:30–7:30 UTC. This is likely related to post-seismic effects in the geomagnetic field as a result of the great earthquake in the Republic of Turkey on February 6, 2023, with a magnitude of 7.8.

Смущения в геомагнитното поле, записани на 06.02.2023

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Ключови думи: геомагнитно поле, смущения, ULF, спектрален анализ

Резюме
Анализирани са данни за вариациите на геомагнитното поле, записани в периода 5-6 февруари 2023г. в три геомагнитни обсерватории- PAG (България), PEG (Гърция) и WIC (Австрия). След прилагането на спектрален анализ и сравняване с параметрите на слънчевия вятър, измененията в стойностите на вариациите междупланетното магнитно поле (Bz), са намерени два типа смущения. Първият тип се проявява като ултра-нискочестотна вълна (в спектъра на Pc3-4 пулсациите) в хоризонталните компоненти и на трите станции. Има начало в 00:52UTC и продължителност около 25 минути. Представяла глобално явление, породено от изменения в стойностите на параметрите на слънчевия вятър. Вторият тип се проявява локално (станция PAG) само в компонентата изток-запад на магнитния вектор. Изразява се в плавно повишение на стойностите ѝ, както и в резки пикове за часовия интервал 1:30 - 7:30 UTC и не е изключено да е свързан с пост-сеизмични ефекти в следствие на голямото земетресение в Република Турция от 6.02.2023 с магнитуд M=7.8.

Introduction
Disturbances in the geomagnetic field in terms of their origin can generally be divided into those of magnetospheric-ionospheric origin, those of intra-terrestrial origin (Li et al., 2019) and disturbances caused by human activity (Villante et al., 2014). The first one is mainly due to the interaction between the solar wind (SW) - fully ionized plasma, and the magnetosphere of the Earth (Němeček et al., 2020). The Alfven waves are magnetic waves that can transfer energy from the surface of the Sun into the solar wind (Gosling et al., 2009). The SW parameters that usually affect the magnetosphere-ionosphere system are for instance the SW plasma speed, the dynamic pressure, the magnetic-field strength, the number density, and other (Borovsky, 2020). There many papers that investigate disturbances in the geomagnetic variations recorded during the geomagnetic storms and during the quiet periods (Chamati, 2022; Chamati and Andonov, 2022; Dahal et al., 2022; Dai et al., 2015; Lakhina and Tsurutani, 2021; Menk, 1988).
In this paper, the two types of geomagnetic disturbances recorded at 1 s resolution on February 5-6, 2023, by three geomagnetic observatories (Panagjurishte (PAG), Bulgaria, Conrad Observatory (WIC), Austria, and Pedeli (PEG), Greece are analyzed and discussed.

Results and discussion