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 Geoinformation Center (Miloshev et al., 2019) as well as information about geomagnetic field elements (Metodiev and Trifonova, 2020).

In terms of their spectral characteristics, the irregular short-term geomagnetic variations with external origin resulting mainly from the impact of the storms and the substorms on the geomagnetic field, cover a wide range of periods and frequencies - from part of second to minutes (Chamati, M., 2018; Chapagain, 2017; Kleimenova et al., 2019; Watermann and Gleisner, 2009).

On 09 October 2021 at 06:38 UT the coronal mass ejection (CME) associated with flare from Region 2882 (N17, L=1.57) has occurred on the Sun. The CME reached the Earth on the 11 October 2021 to early 12 October 2021 and disturbed the Earths magnetosphere, in particular geomagnetic field, and caused a geomagnetic storm at high and mid latitudes.

Measuring instrument

At the Geomagnetic Observatory Panagjuriste, Bulgaria (geographic coordinates: 42.51N/24.18E) operate a tri-axial search-coil magnetometer system which is a part of SEGMA Array (South European Geomagnetic Array, Figure 1). It is designed to measure and collect data for the Earth's magnetic field variations, specific geomagnetic events and



Fig. 1. The map of SEGMA Array and measuring instrument pictures

long-term study of ULF signals. The sensitivity of the measuring instrument is in range 10 mV/nT – 100 mV/nT. The frequency band is 5 mHz – 20 Hz and its intrinsic noise is 0.05 pT/ $\sqrt{((Hz))}$ at 1 Hz. The timing is provided via GPS.

Data set

The acquisition system records originally data sets associated with X (northsouth), Y (east-west) and Z (down/vertical) directions. They are sampled at 100 Hz, organized in files with duration one hour. With aid of some software packages perform verifications of the data files and transform them into data files with duration one hour, sampled at 1 Hz.

Results

At early hours on 12 October 2021 the shock from the coronal mass ejection (CME) arrived resulting in a geomagnetic storm – class G1 increasing to G2 according to classification of BGS (British Geological Survey) categories since 2014. It was recorded by the search-coil instrument at Panagjuriste, Bulgaria, which provides continuous data of ultra-low frequencies of geomagnetic field variations. Figure 2 illustrates the variations of the magnetic field along the X (north-south) and Y (east-west) directions for twenty-three hours. The shock is characterized by sudden decrease in the both values along the X and Y components at 02:26:20 UT (Figure 3). The absolute values of the decrease for the X and Y components are about $2.10^5 \,\mu$ V and $1.10^5 \,\mu$ V, respectively.



Fig. 2. ULF variations along the X and the Y components on12 October 2021



Fig. 3. ULF variations at the beginning of the storm on 12 October 2021, X and Y components

The planetary geomagnetic index - K_p reaches values about 6 during the time intervals 03-06 UT and 09-12 UT (the bottom panel on Figure 4) (Matzka et al., 2021) (https://www-app3.gfz-potsdam.de/kp_index/Kp_ap_Ap_SN_F107_since_1932.txt) while the local K index (Metodiev, M. and Trifonova, P., 2021) (http://data.niggg.bas. bg/magn_data1/pag_archive_bg.php), calculated for Panagjuriste is 5 (upper panel on Figure 4). The local geomagnetic activity remains relatively high after 12 UT while the global index is gradually decreasing.



Fig. 4. The K index, Panagjuriste, Bulgaria (upper panel) and the Kp index (bottom panel) on 12 October 2021

To extract detailed information on the spectral characteristics of the geomagnetic ULF variations along the X and Y components the Wavelet analysis is applied. The time scales 1-900 seconds are analyzed. On Figure 5 the results obtained for the X component are presented. It shows that at the beginning of the storm at the 02:26 UT the sudden powerful disturbance, which comprise the time scales 90-900s, is recorded. At the same time a similar behavior of this disturbance is observed along the Y component (Figure 6). Then, up to about 10 UT, similar power and frequency interferences in time scales 45-350s occur along both directions – X and Y.



Fig. 5. Dynamic spectra, X component on 12 October 2021, PAG station, time in seconds



Fig. 6. Dynamic spectra, Y component on 12 October 2021, PAG station, time in seconds

Bulgarian Geophysical Journal, 2021, Vol. 44

After 10 UT the disturbance strength of the X and Y components (Figures 5 and 6), but not at the time of its occurrence, is very different. Along the X component stronger disturbances, compared with Y component, in time scales 250-450s and 550-900s appear. Three maxima of ULF spectra of the disturbances stand out particularly clearly: about 14:30 UT, 20 UT and 22 UT. The first one covers the time scales 600-900s, the second \sim 270-370s and the third one \sim 700-900s. Figures 6 and 7 show similarities in that almost no timescale disturbances of less than 45 seconds are observed.

Conclusion

On 12 October 2021 the shock from the coronal mass ejection (CME) caused a geomagnetic storm – class G1 increasing to G2. The local spectral characteristics of ULF geomagnetic noise along the X and the Y components, recorded at the Panagjuriste Geomagnetic Observatory have been studied. It is found that the disturbances along the two geomagnetic components have similarities and differences in terms of the time scales in which they occur and also in terms of the time of occurrence. The similarities appear before 10 UT and correspond to time scales 90-900s. The differences between disturbances recorded along X and Y components appear after 10 UT. They occur on the X component and are expressed by strong disturbances (compared to the Y component) in the time scales 600-900s, \sim 270-370s and \sim 700-900s. Along the Y component, after 10 UT, the powerful disturbances are not observed.

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Геомагнитни смущения в ULF диапазон, наблюдавани по време на геомагнитна буря в Геомагнитна Обсерватория Панагюрище

М. Шамати

Резюме. Изследвани са геомагнитните смущения, причинени от геомагнитната буря от клас G1 нарастващ до G2, наблюдавана на 12 октомври 2021 г. Анализирани са данни за ULF вариациите на X и Y компонентите на земното магнитно поле, записани в Геомагнитната Обсерватория "Панагюрище", България, с резолюция 1 секунда. Представени са записите на ULF вариациите от 01:00 UT до 23:59 UT, локалният и глобалният К-индекси и динамичните спектри в ULF диапазона. Установено е, че спектралните характеристики на геомагнитните вариации преди 10 UT, намерени за двете геомагнитни компоненти, имат прилики по отношение на времето на възникване, времевите скали, в които се проявяват и мощността им. След 10 UT резултатите показват радикални разлики в проявите на смущения в двете геомагнитни компоненти на времевите скали, в които се появяват, а също така и по тяхната мощност.