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).

The geomagnetic storms are natural phenomena which are directly linked with the Solar activity. Depending on the latitude, they cause disturbances in the Earth's magnetic field which can be recorded on the ground. The records include among other "noises" of different type of sources, such as magnetospheric/ionospheric, atmospheric, lithospheric and anthropogenic (Chamati and Botev, 2019; Klimenko et al., 2018; McPherron, 2005; Nenovski et al., 2013; Villante and Vellante, 1998). By studying of the geomagnetic field variations and disturbances caused by natural phenomena the useful information about the Solar-terrestrial interactions is provided (Blagoveshchensky and Sergeeva, 2018; Borovsky, 2020). Irregular short–term geomagnetic variations of the geomagnetic field due to storms and substorms have peculiar spectral characteristics covering a multitude of periods ranging from a part of second to a few minutes (Chapagain, 2017; Kleimenova et al., 2019; Watermann and Gleisner, 2009).

Measuring instrument

At the Geomagnetic Observatory Panagjuriste, Bulgaria (geographic coordinates: 42.51N/24.18E) operate a tri-axial search-coil magnetometer. It is designed to measure and collect data of the Earth's magnetic field variations, specific geomagnetic events and 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/√((Hz)) at 1 Hz. The timing is provided via GPS.

Data set

The acquisition system records original data sets associated with X (north-south), Y (east-west) and Z (down/vertical) directions. They are sampled at 100 Hz, organized in files with duration one hour. With the aid of some software packages, it performs verifications of the data files and transform them into data files, sampled at 1 Hz. The data sets collected for the X and the Y components of the ULF geomagnetic field variations for the period 27-28 September 2017 are analyzed. The data sets for the values of the local *K* (Metodiev, M. and Trifonova, P., 2021) and the global *Kp* indices for the above mentioned period were downloaded from: http://www.niggg.bas.bg/observatories-bg/geomagnetic-observatory-pag/%D0%BB%D0%BE%D0%BA%D0%B0%D0%BB%D0%BD%D0%B8-%D0%BA-%D0%B8%D0%BD%D0%B4%D0%B5%D0%BA%D1%81%D0%B8/ https://www.spaceweatherlive.com/en/auroral-activity/top-50-geomagnetic-storms/year/2017.html

Results and discussion

On 27 September, 2017 at 08:48 UTC a Minor geomagnetic storm level (G1) took place. Later at 20:24 UTC on 27 September it was followed by a G2 - Moderate level storm and then increased to G3 - Strong one on 28 September, 2017. On Figure 1 the ULF

geomagnetic field variations along the X (north-south), the Y (east-west) and the Z (vertical) directions are presented. It is visible that variations along the three directions during the whole investigated period – 27/28 September 2017 are disturbed.

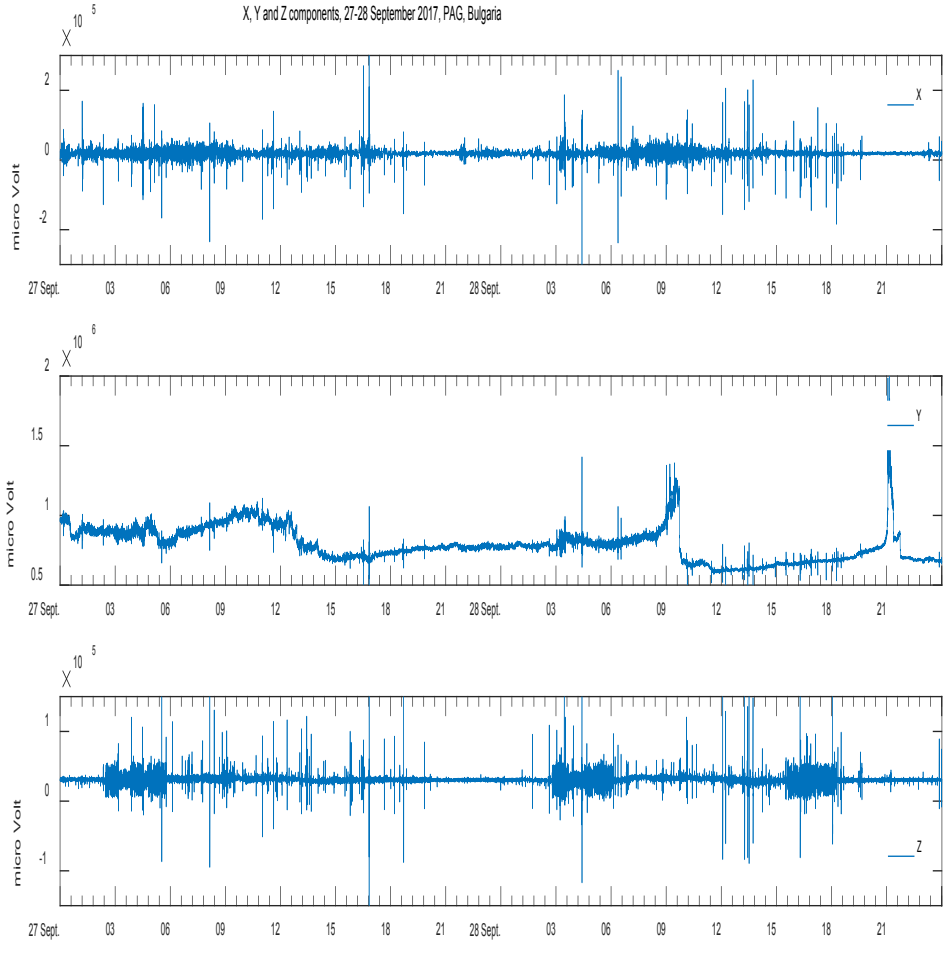

Fig. 1. ULF variations along the X, the Y and the Z components on 27-28 September 2017

Figure 2 shows *Kp* index (https://www.spaceweatherlive.com/en/auroral-activity/top-50-geomagnetic-storms/year/2017.html) calculated for the investigated period.

On 27 September in the time interval 06-09 UTC *Kp* index reached a value 5 and the local *K* index reached a value 4 (Figure 3). Later, when the storm increased to Moderate level-G2 and *Kp*=6, the local index takes value *K*=5. Finally, the storm reaches its Strongest level on 28 September when *Kp* becomes value 7 in the time interval 06-09 UTC.

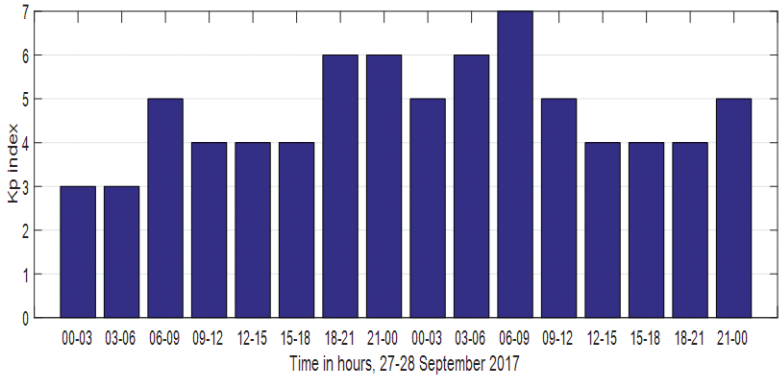

Fig. 2. *Kp* index, 27-28 September 2017

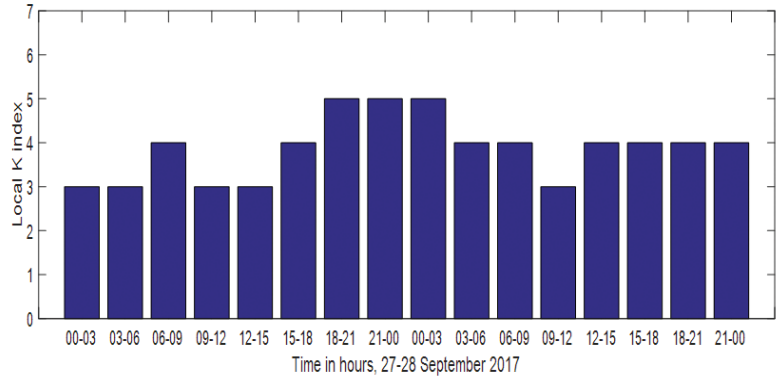

Fig. 3. The local *K* index, Panagjuriste, 27-28 September 2017

Morlet wavelet analysis is applied on time series with recorded data along the two investigated directions (X and Y) of the ULF geomagnetic field variations. The time scales 1-600s (in range of continuous *Pc1-5* and irregular (*Pi 1-2*) pulsations (partly in *Pc1* and *Pi1*)) are analyzed. On Figure 4 the results obtained for the X component are presented. All investigated time scales are disturbed and the power of the disturbances is greatest when *Kp* index reaches the highest values. Figure 5 shows the results obtained for the Y component. Here, simultaneous but weaker disturbances compared to those of the X component are observed. Two powerful disturbances stand out- the first one about 09 UTC on 28 September and the second one about 21 UTC at the same day. They fully correlate with *Kp=7* and *Kp=5*. The X component, during above mentioned hours, does not reflect such powerful interference.

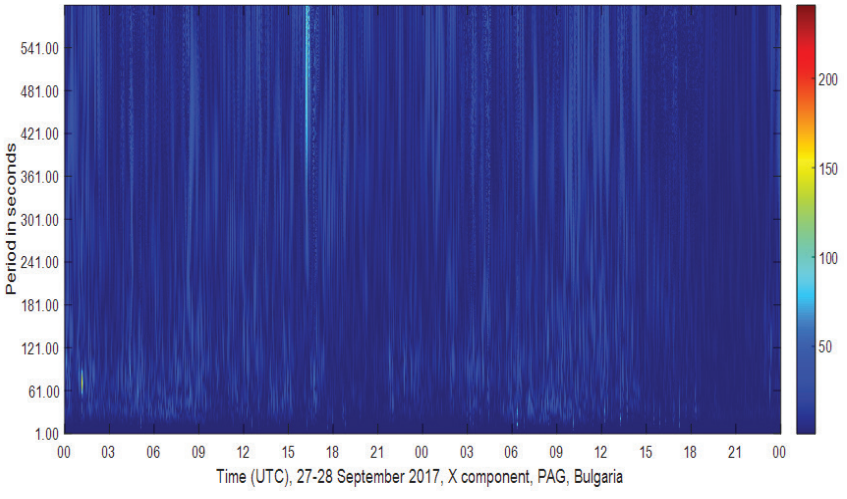

Fig. 4. Dynamic spectrum, X component on 27-28 September 2017, PAG station

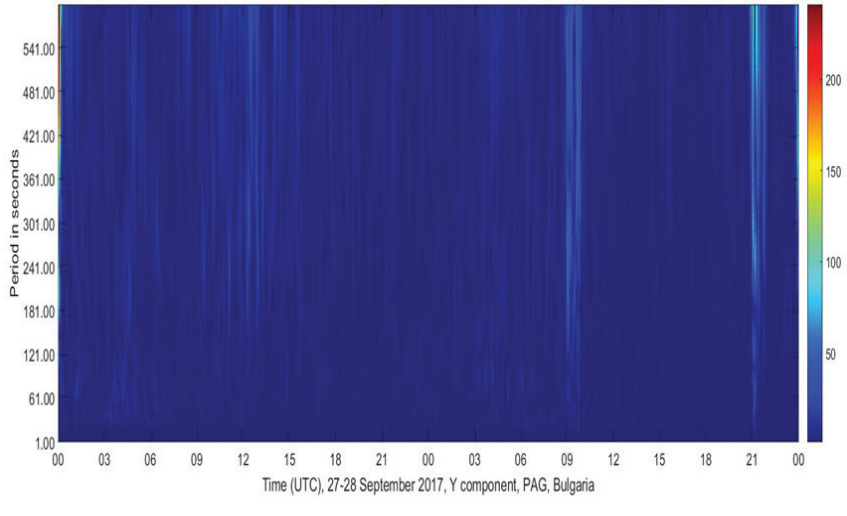

Fig. 5. Dynamic spectrum, Y component on 27-28 September 2017, PAG station

The time interval 00-03 UTC (27 September 2017) on Figure 4 shows disturbances along the X component in time scales about 60-120s, which are not observed at the same time along the Y component (Figure 5).

On Figure 6 are presented ULF variations along the X component (top panel) and dynamic spectrum (bottom panel) for the same component on 27 September 2017 for the time interval 00-03 UTC. About 00:10 UTC and 01:10 UTC are observed pulsations

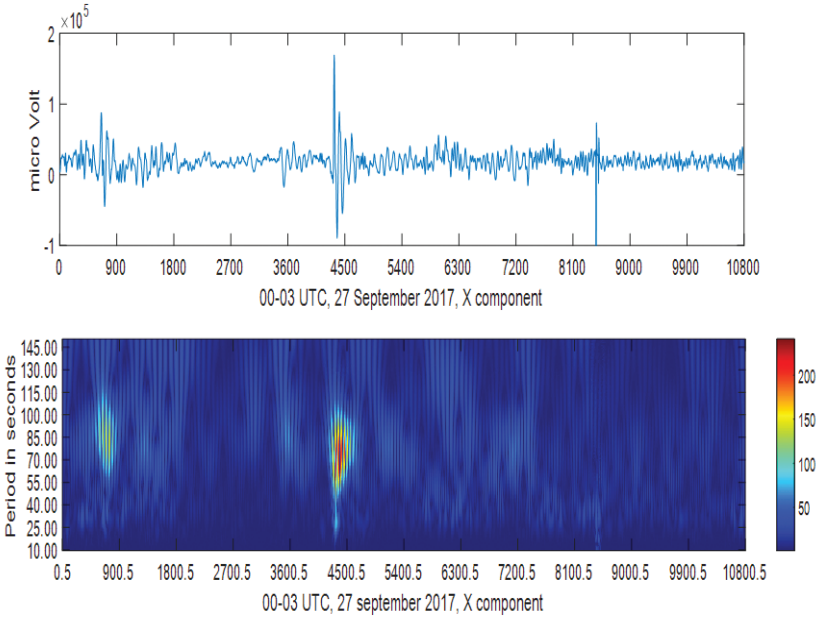

Fig. 6. ULF variations, X component (top panel) and dynamic spectrum (bottom panel), X component on 27 September 2017, 00-03 UTC, PAG station, time in seconds

which lasting a few minutes. On the bottom panel on Figure 6 the dynamic spectrum shows that these pulsations have periodicity covers time scales 40-110s and main period about 85s (in *Pc4* range, possible related to injections of energetic plasma).

Conclusions

On 27-28 September 2017 the geomagnetic storm was recorded at Geomagnetic Observatory Panagjuriste. The storm begins as a Moderate level-G2 on 27 September and on 28 September increasing to Strong level-G3. At Panagjuriste Observatory the storm reached level G2. To investigate the spectral characteristics of the storm Morlet wavelet analysis is applied over the time series which contain data records of ULF geomagnetic variations along the X and Y components. The time scales (1-600s) corresponding to both continuous (*Pc1* (partly) - *Pc5)* and irregular (*Pi1* (partly) - *Pi2*) pulsations are analyzed. The obtained results show that along the X and Y components all investigated scales are disturbed and it agrees with local and planetary *K* indices. The most powerful interferences along the Y component (at 09UTC and 21UTC on 28 September) strongly correspond with the value of *Kp* index, but not with that of the local K index. It was found that on 27 September 2017 in time interval 00-03 UTC pulsations in Pc4 range appeared. They have periodicity which covers time scales 40-110s and main period about 85s and they are most likely related to injections of energetic plasma.

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Спектрални характеристики в ултра-нискочестотен диапазон на геомагнитната буря от 27-28 септември 2017 г., наблюдавана в Геомагнитна обсерватория Панагюрище

М. Шамати

Резюме. Изследвани са геомагнитните смущения и техните спектрални характеристики, причинени от геомагнитната буря от клас G1 нарастващ до G3, наблюдавана на 27-28 септември 2017 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 00:00 до 23:59 UTC за двата, изследвани дни, локалният и глобалният K-индекси и динамичните спектри в ULF диапазона. Установено е, че спектралните характеристики на геомагнитните вариации, намерени за двете хоризонтални (Х(север-юг) и У(изток-запад)) геомагнитни компоненти, имат сходства по отношение на времето на възникване, времевите скали, в които се проявяват, а именно 1-600 секунди, като смущенията кореспондират по време с локалния и глобалния К индекси. По направлението север-юг в часовете 09UTC и 21UTC на 28 септември 2017 се наблюдават смущения, които кореспондират с глобалния К индекс, но не и с локалния. На същия ден в часовия диапазон 00-03UTC са намерени пулсации, които имат основен период около 85 секунди и се наблюдават единствено по направлението север-юг.