



# Detection of long period Pc5 pulsation during 01st/Jul/2011 to 30th/Jun/2012 recorded at Egyptian and some INTERMAGNET observatories

Mohamed A. El-Eraki <sup>a</sup>, Taha Rabeh <sup>b</sup>, Ahmed Lethy <sup>b</sup>, Essam Ghamry <sup>b,c,\*</sup>,  
Aalaa Samy <sup>b</sup>

<sup>a</sup> Faculty of Science, Zagazig University, Egypt

<sup>b</sup> National Research Institute of Astronomy and Geophysics (NRIAG), Helwan 11722, Egypt

<sup>c</sup> School of Space Research, Kyung Hee University, Yongin, Gyeonggi-Do 446-701, South Korea

Received 21 October 2013; revised 22 October 2014; accepted 2 November 2014

Available online 20 November 2014

## KEYWORDS

Pc5 pulsation;  
Misallat;  
Abu-Simple magnetic  
observatories

**Abstract** The long period Pc5 pulsations (1.7–6.7 mHz) have been observed at Misallat observatory during the period 01/Jul/2011 to 30/Jun/2012. The study correlates the Pc5 intensity during day and night times. We present a case study of Pc5 pulsation observed in the 08–12 UT time intervals during the initial phase of the magnetic storm of October 5th, 2011. We use data from Misallat and Abu-Simple magnetic observatories in Egypt and other four observatories (Addis Ababa, Tamanrasset, L'Aquila and Belsk) belonging to the INTERMAGNET network. We propose that the source of this pulsation is identified as compressional waves caused by fluctuations of the solar wind dynamic pressure.

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## 1. Introduction

Ultra-low-frequency (ULF) waves were first observed in ground-based magnetometer measurements more than a century ago by Stewart (1861) including the appearance of quasi-sinusoidal magnetic oscillations with periods of a few minutes (150–600 s), now categorized as Pc5 oscillations (Jacobs et al., 1964). There are several properties of pulsations to be taken into account in such studies: frequency characteristics, including harmonic structure, spatial distribution, polarization properties, correlation with solar wind parameters,

\* Corresponding author at: National Research Institute of Astronomy and Geophysics (NRIAG), Helwan 11722, Egypt and School of Space Research, Kyung Hee University, Yongin, Gyeonggi-Do 446-701, South Korea.

Peer review under responsibility of National Research Institute of Astronomy and Geophysics.



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relation to geomagnetic activity, for example phases of storms and substorms, and correlation with particle signatures (Hudson et al., 2004).

The magnetic pulsations recorded by a network of magnetometers are useful tools to investigate the complex magnetospheric processes, in general, and to understand the generation and propagation mechanisms of ULF waves. There has been good progress in the theory of pulsations during the last two decades, especially for continuous pulsations. These pulsations are useful in the diagnosis of the near-Earth plasmas, fields and their interactions. Long records of pulsations at observatories are important in investigating the long-term variability of the plasma regions.

Pc5 polarization appears predominantly counterclockwise in the morning, but clockwise in the evening. This diurnal feature is entirely opposite in the southern auroral zone. In middle latitudes, both morning and evening sides seem to be further divided into day-sides and night-sides, respectively, making four sectors in which Pc5 polarization changes alternatively from counterclockwise to clockwise (Sano, 1963; Saito, 1964).

Pc5 pulsation represents the longest hydromagnetic waves, which can exist in the dayside magnetosphere (Ghamry, 2008). Geomagnetic pulsations in the Pc5 band ( $f \approx 1.5\text{--}7$  mHz) are probably the most easily observed ULF waves. Due to their large amplitudes (up to some 100 nT) and long periods (several minutes) Pc5 pulsations can even be detected in magnetograms with low sensitivity and low sampling rate, e.g., 1 min. Pc5 pulsations may play a pivotal role in the acceleration of electrons to relativistic energies in the outer radiation belt through the process of drift resonance (e.g., Elkington et al., 1999, 2003; Hudson et al., 2001; Mann et al., 2004; Degeling et al., 2007).

The present work aims to study the long period continuous pulsations Pc5 recorded in Misallat geomagnetic observatory during quiet and disturbed days from 1st July 2011 until 30th June 2012. Also, we present a case study of Pc5 pulsation observed in the initial phase of the magnetic storm of October 5th, 2011.

## 2. Data set

The used geomagnetic data are obtained from two sources:

The first source is the Egyptian geomagnetic observatories Misallat (MLT) and Abu-Simple observatories, while the second source is the INTERMAGNET observatories: Addis Ababa (AAE), L'Aquila (AQU), Belsk (BEL), Tamanrasset (TAM) (Fig. 1).

**Table 1** Geomagnetic observatories used in this study.

Station name	Code	Geographic		Country
		Lat.	Long.	
<i>Egyptian geomagnetic observatories</i>				
Misallat	MLT	29.44	30.53	Egypt
Abu-Simbel	ABS	22.4896	31.5453	
<i>INTERMAGNET stations</i>				
Addis Ababa	AAE	9.03	38.77	Ethiopia
L'Aquila	AQU	42.383	13.317	Italy
Belsk	BEL	51.837	20.792	Poland
Tamanrasset	TAM	22.79	5.53	Algeria

Table 1 indicates the code of the magnetic observatories and their geographic coordinates.

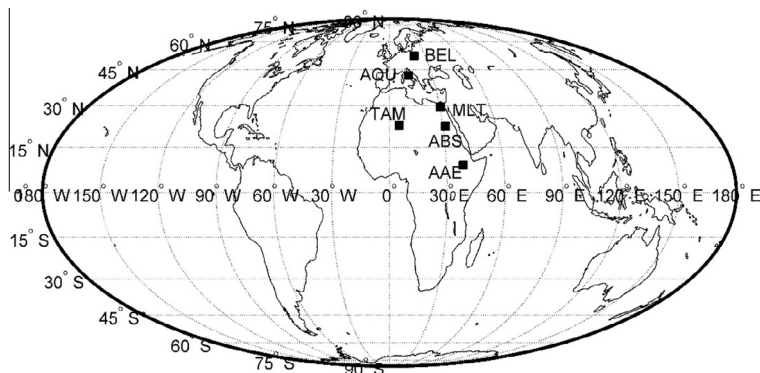
## 3. Detection of Pc5 pulsation in Misallat observatory

Analysis of temporal variations of the Pc5 pulsation parameters is done through several steps. The first step, is using MATLAB program and its functions such as the application of the filter technique using a zero phase shift second order butterworth band pass in the period range of 150–600 s on the one-minute raw data of the geomagnetic X-component in Misallat observatory to all the days during the year. The X-component and the detected Pc5 pulsations are plotted for all days. Fig. 2 shows an example of band pass filter of the X-component at MLT observatory on 25th August, 2011.

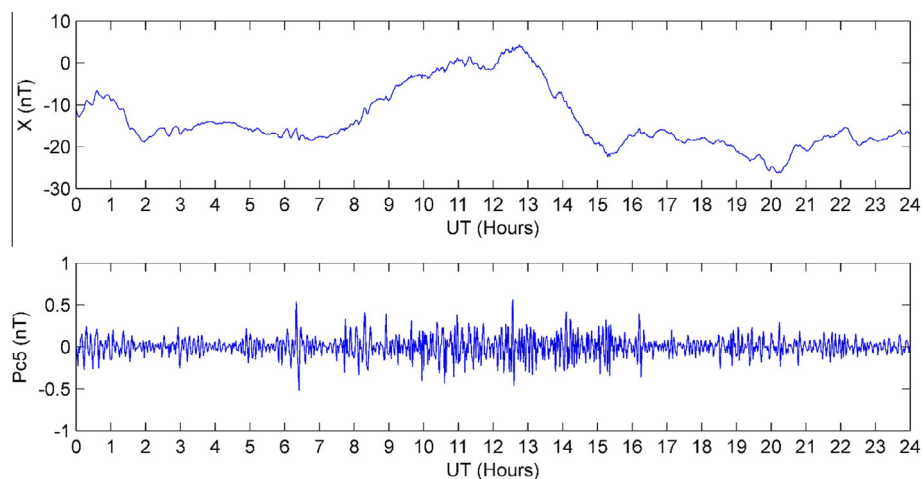
The second step is to construct a 2D diagram on the raw geomagnetic data of Misallat observatory to study the behavior of the Pc5 from day to day. Fig. 3 shows the diagram for the period of study obtained by MATLAB. The diagram demonstrates temporal variations of the observed amplitude of the Pc5 (linear color scale) as a function of the observation time in minute (vertical scale) and the day of observation (horizontal scale).

1. From day No. 20 until day No. 22.
2. From day No.72 until day No. 75.
3. From day No. 90 until day No. 94.
4. From day No. 254 until day No. 256 and
5. From day No. 340 until day No. 345.

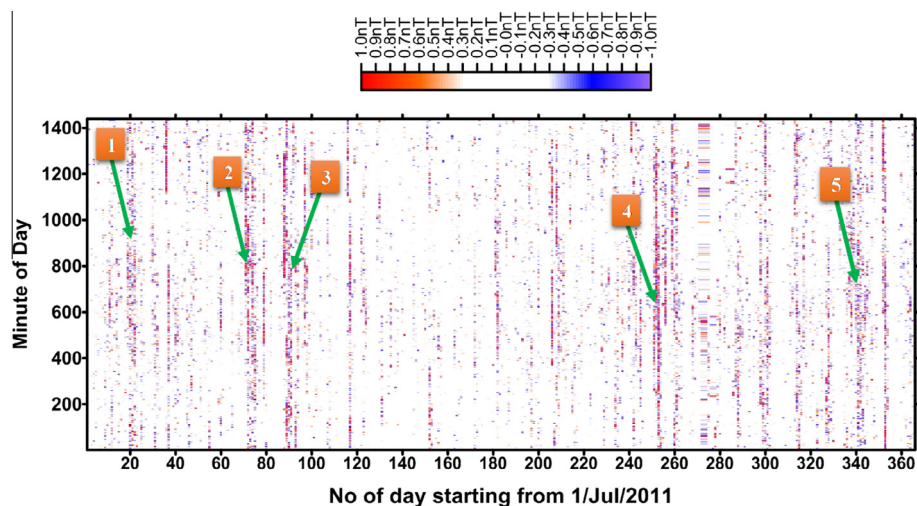
The third step is the application of the dynamic spectrum on the raw magnetic data of Misallat observatory to study Pc5 spectral structure. Fig. 4 shows the spectrogram for the



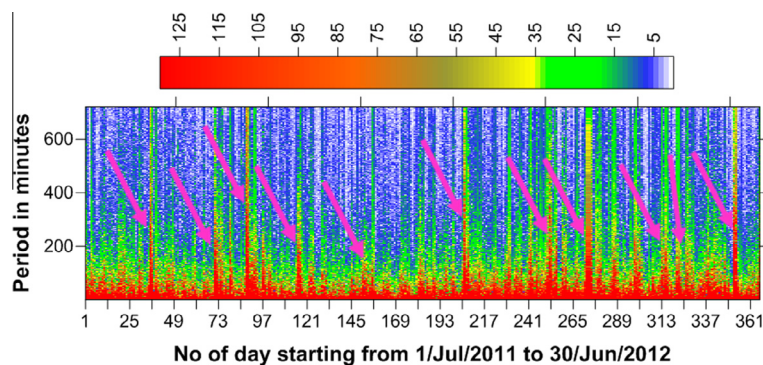
**Figure 1** Location of stations used in this study.



**Figure 2** Band pass filter of X-component at MLT observatory on 25th August, 2011.



**Figure 3** A 2D diagram on the raw geomagnetic data of Misallat observatory.



**Figure 4** The spectrogram of the X-component of MLT observatory during the period of the study.

period of the study. The plot demonstrates the observed power intensity (linear scale) as a function of the period in minute for vertical scale and the number of day started from 1 July 2011 to 30 June 2012.

There is an enhancement in the Pc5 in many days during the period of study (as marked by pink arrows), as shown in Fig. 4. The long period pulsation has a continuous occurrence during the study period.

#### 4. Case study: magnetic storm of October 5th, 2011

A CME hit Earth's magnetic field on October 5th, 2011 at approximately 0700 UT, sparking minor geomagnetic storms around both poles. The interplanetary shockwave reached the magnetosphere at 07:36 UT on October 5th, 2011, giving rise to the onset of a geomagnetic storm. Fig. 5 shows the Dst index on October 5th, 2011.

The Raw data of all the stations as well as Misallat and Abu-Simbel observatories on October 5th, 2011 are shown in Fig. 6. The onset of the storm is clearly seen at all stations which are shown by a dashed line.

We can notice the Pc5 pulsation observed in the 08–12 UT time intervals during the initial phase of the magnetic storm. So, a magnetogram stackplot (filtered data 150–600 s) from six stations from 8 to 12 UT is shown in Fig. 7. First of all, the general similarity of the signals over the whole plot is

clearly seen. The band base filter shows that the main peak appears in the range  $\sim 9.15$ – $10.15$  UT at all stations. We can observe that the Pc5 maximum amplitude exceeds 2 nT at mid-latitude observatory BEL due to its location at higher latitude than the other stations. Also, we can observe that the Pc5 maximum amplitude exceeds 2 nT at the equatorial station AAE due to the equatorial electrojet, which is characterized by zonal ionospheric conductivity during the daytime (Chapman, 1951). The Pc5 does not reach this magnitude at other stations.

To demonstrate the spectral analysis of the main peak of the Pc5 pulsation, we perform the Power Spectrum Density in the range of an hour (9.15–10.15 UT). The result shows that the main peak appears in the range of 0.8–1.0 mHz at all stations (Fig. 8). We can observe that the AAE and BEL stations have the higher amplitude than other stations due to reasons mentioned above.

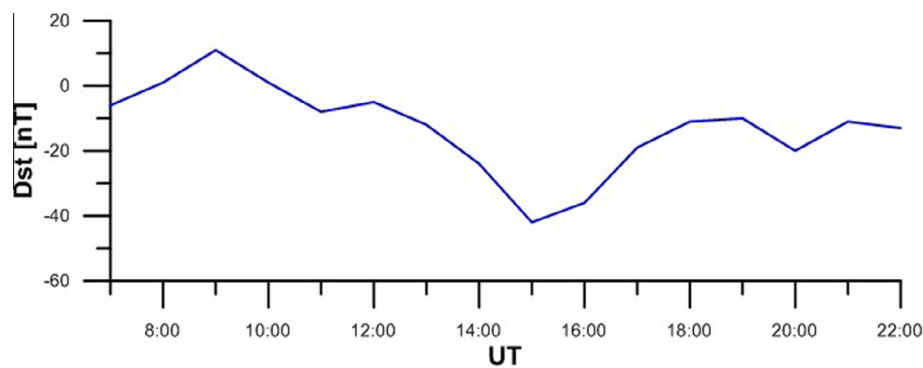


Figure 5 The Dst index on 5th October 2011.

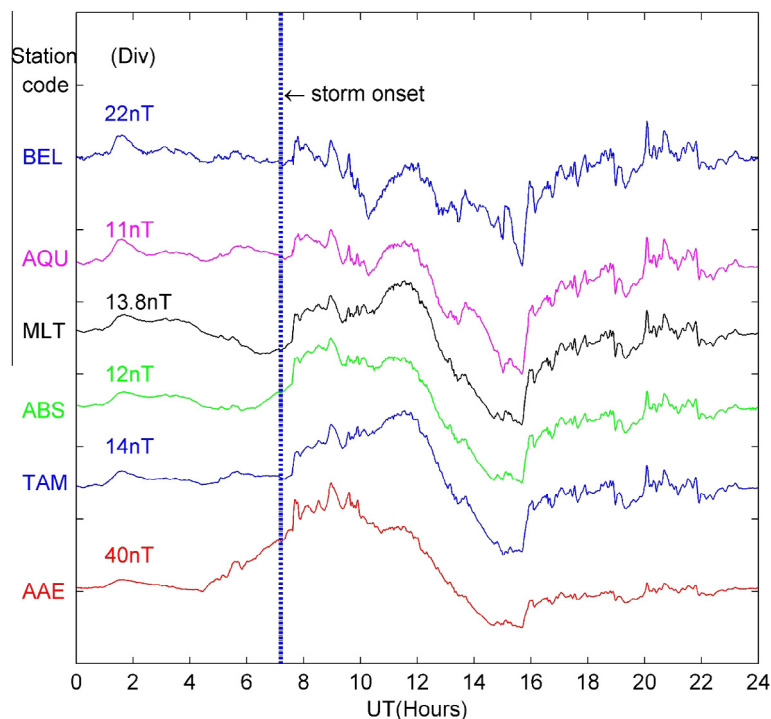
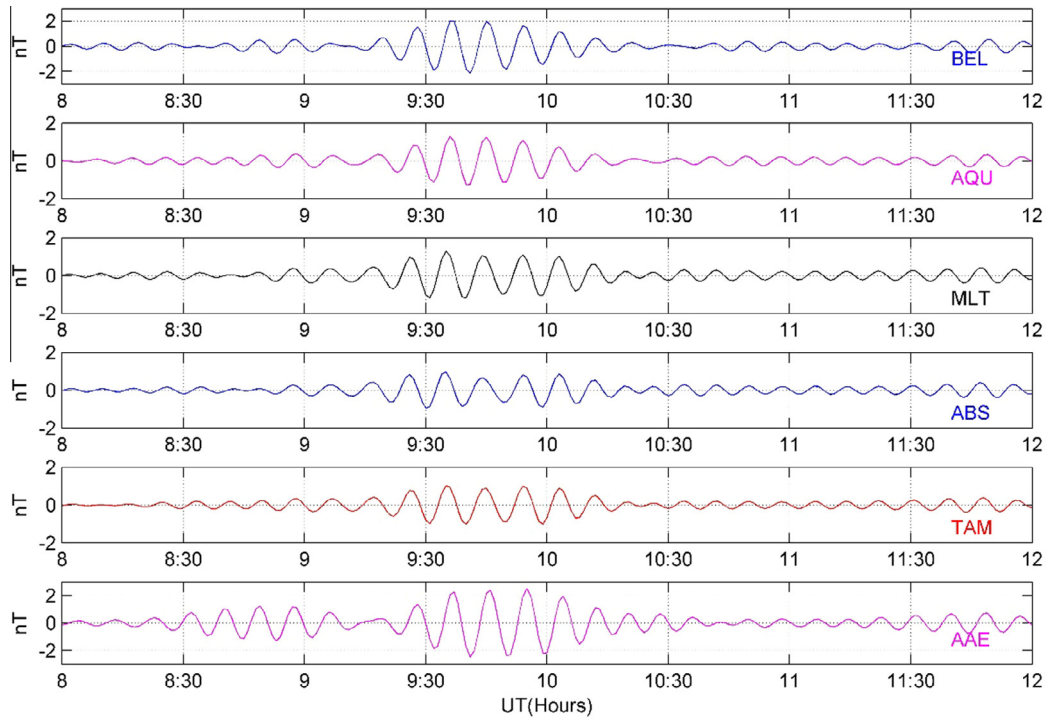
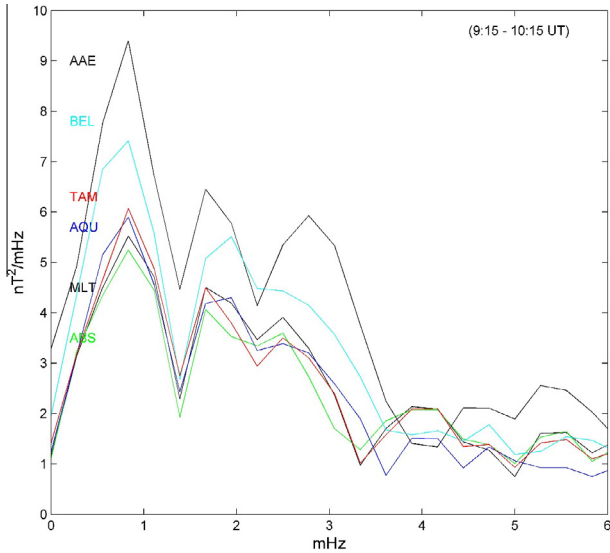


Figure 6 Raw data of all stations on 5th October 2011.





**Figure 7** Band pass filtered data from 8 to 12 UT of all stations on 5th October 2011.



**Figure 8** Spectral analysis in the range of 9.15–10.15 UT of all stations on 5th October 2011.

## 5. Discussion

The similarity of wave spectra at low latitude stations (TAM, AQU, MLT and ABS) and the nearly simultaneous appearance of separate wave packets allow us to conclude that they are originated from a common source, for example, triggered by a succession of impulses. The main pulsation period in

the interval 8–12 UT was practically the same in all stations, independent on latitudes. Several other assumptions may be imagined in order to predict the Pc5 pulsation generation. It could be the result of modulation (ringing) of a three dimensional field aligned current system (Lam, 1989), but this mechanism is very doubtful because the Pc5 pulsations were observed near local noon. Another possibility relies upon instabilities on the boundary between the low latitude boundary layers (LLBL) and the magnetopause, as it was proposed by Engebretson et al. (1983). Kivelson et al. (1984) proposed a mechanism of wave generation connected with fast mode resonance of the entire magnetospheric cavity located between the magnetopause and the inner turning point or at least the sunward half of the cavity. Because of the radial gradient of Alfvén speed, the turning point of waves could coincide with the plasmapause. According to analytical models of a global compression mode (for instance, Kivelson et al., 1984) the waves are reflected, on one side, on the sharp gradient of the magnetic field of the magnetopause and, on the other side, on the plasma density gradient near the plasmapause. The poloidal global mode is characterized by azimuthal electric field oscillations and radial motions of the plasma. The most relevant mechanism might be the model of wave guide modes proposed by Samson and Harrold (1992). The pulsations could be initiated by solar wind disturbances perturbing the magnetopause. According to Zhu and Kivelson (1994), compressional pulsations in the daytime magnetosphere are characterized by very low frequencies, are nearly monochromatic and extend over regions several  $R_E$  large in the radial direction. This description matches the 8–12 UT Pc5, which might be therefore identified as compressional waves caused by fluctuations of the solar wind dynamic pressure, as proposed by Fujitani et al. (1993).

## 6. Conclusion

No clear correlated pattern was observed between day and night pulsations during the period of the study at Misallat observatory. Pc5 pulsation event occurring in the daytime at Misallat observatory can help for studying the characteristics of Pc5 pulsation and will benefit for the new ULF wave index which has been calculated using magnetometer data from geostationary (GOES) and interplanetary (ACE) satellites.

We presented a case study of Pc5 pulsation observed in the 08–12 UT time intervals during the initial phase of the magnetic storm of October 5th, 2011. We propose that the source of this pulsation might be identified as compressional waves caused by fluctuations of the solar wind dynamic pressure, as proposed by Fujitani et al. (1993).

The Pc5 amplitude is high in Addis Abba (AAE) & Belsk (BEL). This is because AAE is affected by Equatorial Electrojet (EEJ) and BEL is affected by polar aurora. Pc5 amplitude is low in Misallat (MLT), Tamanrasset (TAM) and L'Aquila (AQU).

## Acknowledgment

The results presented in this paper rely on data collected from magnetic observatories. We would like to thank the international real-time magnetic observatory network (INTERMAGNET) for promoting high standards of magnetic observatory practice ([www.intermagnet.org](http://www.intermagnet.org)).

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