ULF MAGNETIC OBSERVATIONS: A USEFUL TOOL TO INVESTIGATE THE OCCURRENCE OF EARTHQUAKE PRECURSORS?

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SUMMARY

In the last two decades many researchers investigated ULF (Ultra-Low-Frequency) magnetic data in the hope of finding pre-earthquake seismogenic signals. Several ULF stations were installed and many papers documented the observations of pre-earthquake magnetic anomalies. These claims motivate the belief that one day short-term earthquake prediction based on magnetic data may become a routine technique. Since the earthquake prediction is a very important topic of social importance, recently some researchers gave rise to a re-examination process of controversial scientific claims and they published their findings. These authors demonstrated that many presumed seismogenic signatures were normal variations driven by the geomagnetic activity. Here, some examples of presumed earthquake precursors are reported hoping to shed light on the usefulness of the ULF magnetic measurements to study the occurrence of pre-earthquake seismogenic signals.

1. INTRODUCTION

The history of ULF earthquake magnetic precursors can be summarized as follow:

i. Fraser-Smith et al. (1990) documented the occurrence of possible ULF magnetic earthquake precursory signals before the Loma Prieta 1989 earthquake. Campbell (2009) and Thomas et al. (2009a) put into question the seismogenic origin of this precursor. Fraser-Smith et al. (2011) reaffirmed the possibility that the Loma Prieta precursor may have a seismogenic origin.
ii. After Fraser-Smith et al. (1990) ULF stations were installed in order to study earthquake precursors and a huge number of papers claimed the observation of magnetic ULF earthquake-related signatures using different methods of analysis.
iii. Recent studies re-examined dubious earthquake precursors and demonstrated that many presumed precursors were normal signatures induced by the normal geomagnetic activity.

The starting points of this re-examination process are:

i. Any potential anomaly, before to be considered a reliable earthquake precursor, should be excluded as a random anomaly or as an anomaly related with other possible sources, both natural and artificial.
ii. According to the normal scientific process, further independent confirming measurements are required before such magnetic field changes can be referred to definitively as precursors.

Here, some examples of the results obtained using different methodologies which were claimed to be useful tools to investigate the occurrence of ULF magnetic seismogenic signals are reported.

2. FRACTAL ANALYSIS

Several researchers, by means of the investigation of changes in the fractal parameters (i.e. the spectral index, the fractal dimension, and the multi-fractal parameters) of the geomagnetic field components, claim the observation of pre-earthquake magnetic anomalies. Recently, Masci (2010, 2012c) demonstrated that these changes in the fractal parameters were actually signals induced by the normal geomagnetic activity. As example, in Figure 1 is reported the fractal dimension changes of the geomagnetic field Z component during the period of the Sumatra 2004-2005 earthquakes. Saroso et al. (2009) claimed that the fractal dimension is affected by the seismic activity. ΣKp index time-series has been superimposed onto the original view. The figure shows that there is a strong correlation between the fractal dimension and the geomagnetic ΣKp index time-series. Thus, the fractal dimension variations are undoubtedly induced by the normal geomagnetic activity and nothing can be related to the preparation process of Sumatra earthquakes. See Masci (2010) for details.

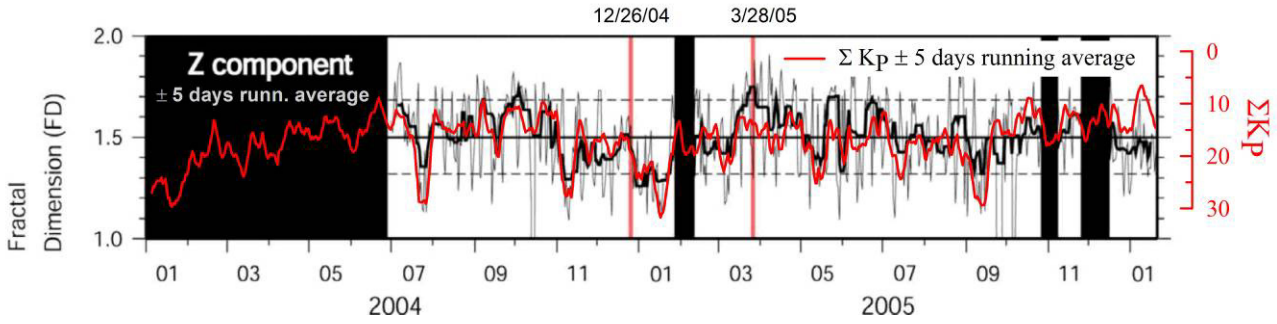

Figure 1 –Fractal dimension time-series of the geomagnetic field Z component as reported by Saroso et al. (2009) compared with the ΣKp index.

3. POLARIZATION RATIO

Many researchers consider the investigation of the magnetic field polarization ratio as a key parameter that allows us to distinguish the normal ULF geomagnetic field pulsations from other signals such as possible seismogenic emissions. The magnetic polarization ratio is defined as the ratio between the integrated (in a fixed range of frequency) power of the vertical component Z and one of the horizontal components H and D. Thomas et al. (2009b) and Masci (2011a, 2012a, 2012b) showed that presumed seismogenic magnetic pre-earthquake polarization ratio variations were actually normal signals induced by the solar-terrestrial interaction.

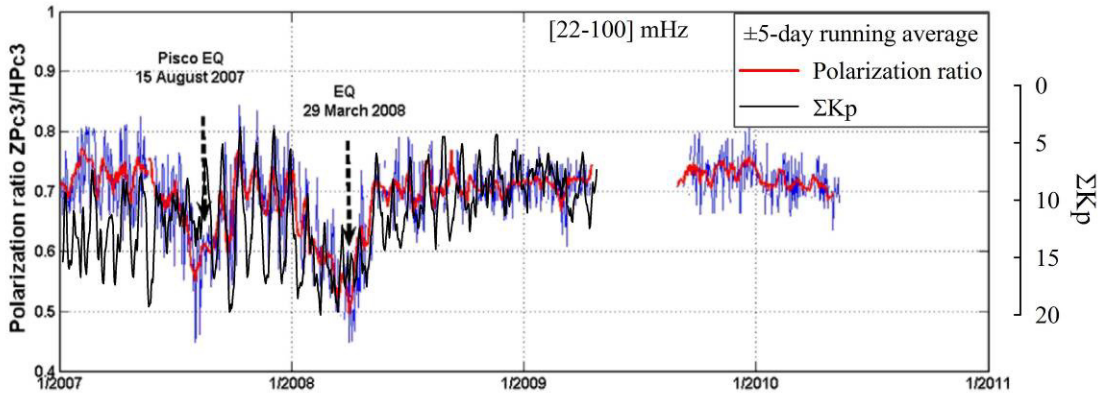

Figure 2 –Polarization ratio Z/H during the period of the 2007-2008 Peru earthquakes compared with the ΣKp index.EQ: Earthquake.

Figure 2 shows the polarization ratio analysis during the period of two Peru earthquakes as reported by Takla et al. (2012). The authors claimed that the polarization ratio decreases which occurred before the two earthquakes are undoubtedly earthquake-related signatures. Conversely, Figure 2 shows a close inverse correlation between the polarization ratio Z/H and ΣKp index time-series which has been superimposed onto the original view. Thus, the two polarization ratio decreases were undoubtedly induced by changes of the geomagnetic activity level.

4. PRINCIPAL COMPONENT ANALYSIS

Figure 3 shows the increases (see the envelope curve) of the third Principal Component Analysis eigenvalue λ_3 of the geomagnetic field H component before the IZU swarm 2000. Hayakawa (2011), by drawing the envelope curves connecting λ_3 peaks, claims that the λ_3 increases were induced by the preparation process of the IZU earthquakes, as well as correlated with the effect of Earth's tides. However, by drawing the envelope curves connecting the peaks of the global geomagnetic Ap index, we can see that there is an inverse correlation between the envelope curves of λ_3 and Ap. The inverse correspondence is evident in the majority of the periods delimited by vertical dotted green lines; this correspondence fails only during some periods. Obviously, the choice of the peaks used to draw the envelope curves could influence their shape. Therefore, we do not expect that a strict inverse correspondence always exists between λ_3 and Ap. However, the inverse correspondence between the envelope curves of λ_3 and Ap in the majority of the periods suggests us a possible relation between λ_3 and the global geomagnetic activity (see Masci, 2011b for details). In summary, connecting the λ_3 increases with the earthquakes occurrence is an oversimplified assumption.

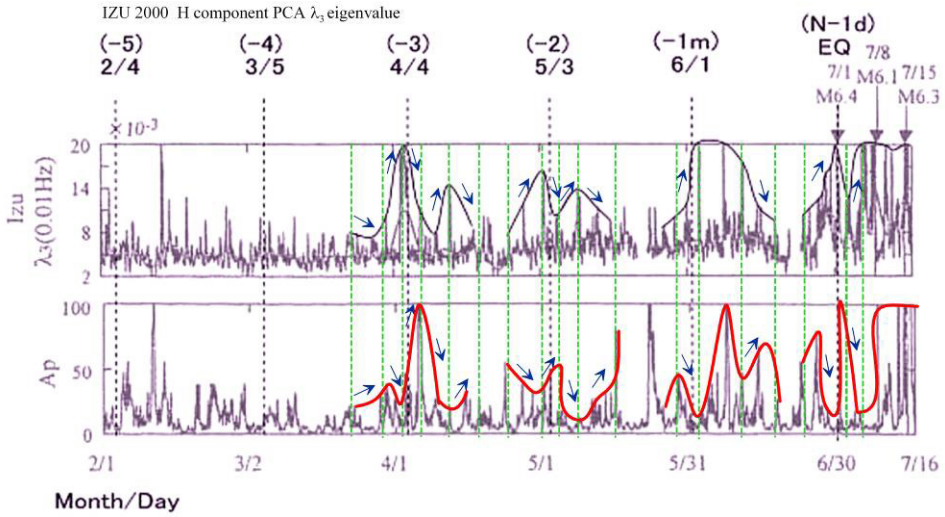

Figure 3 –Third PCA eigenvalue λ_3 increases before the IZU swarm 2000 compared with the Ap index time-series.EQ: Earthquake.

5. RATIO BETWEEN CONJUGATE STATIONS

Takla et al. (2011) claim the observation of Pc 3 anomalous variations possibly associated with two Mw5.7 earthquakes occurred respectively on 31 October and 1 November 2002 in the Molise region, Italy. The authors compare geomagnetic field data from the stations of L'Aquila (LAQ) and Hermanus (HER), which is the almost conjugate point of L'Aquila. According to the authors, in conjugate stations the Pc 3 pulsations have the same amplitude, therefore the anomalous increase of the LAQ/HER ratio during October 2002 (see Figure 4) is related to the Pc 3 amplitude increase at LAQ station caused by the preparation process of the Molise earthquakes.

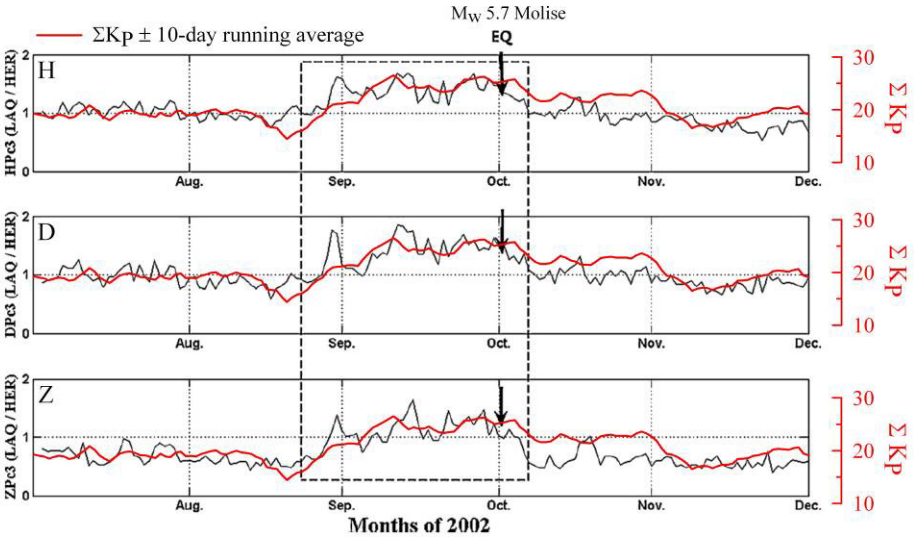

Figure 4 –Pc 3 amplitude ratios between the conjugate stations LAQ and HER during the period August-November 2002 compared with the ΣKp ±10-day running average.

As the matter of fact, Figure 4 shows that the Pc3 LAQ/HER ratio is close related to the long-term variation of the geomagnetic index ΣKp (see the ΣKp ±10-day running average). This suggests that the Pc3 ratio increase which occurs during October 2002 could be induced by the long-term increase of the normal geomagnetic activity. Namely, in conjugate stations the amplitudes of Pc3 pulsations are not always equal even if they may be of the same order of magnitude. As a consequence, we should not expect that in conjugate stations the Pc 3 amplitude ratio is always almost constant. Bearing in mind these considerations, we can suppose that the increase of LAQ/HER ratio during October 2002 may be related to a residual signal caused by the different amplitude of Pc 3 in the two conjugate stations. In conclusion, the Pc 3 ratio increase during October 2002 seems to be induced by the raise of the global geomagnetic activity. Therefore, this increase cannot be undoubtedly associated with the preparation process of the Molise earthquakes.

6. CONCLUSIONS

All the methodologies here reviewed do not show strong evidence of correlation between the presumed precursors and the subsequent earthquakes. In contrast, the authors which have investigated the reliability of presumed ULF precursors have shown that there is a close

correspondence between these precursors and the normal global geomagnetic activity level. Therefore, previously reported associations with the preparation process of the earthquakes occurrence are not correct. In my opinion, the authors documented the observation of pre-earthquake anomalous signals without properly investigate the influence of other possible ULF sources, as well as the geomagnetic activity which is the main source of ULF signals. In summary, the methodologies which were used in investigating ULF seismo-magnetic signals show some problems of fundamental importance. In addition, I would like to emphasize that, a single analysis by itself cannot establish if an anomaly is a seismogenic signal, or is just a chance event induced by other sources, either natural or artificial. Consequently, a more careful approach should be adopted before claiming that any ULF pre-earthquake anomalous observation is a precursory signal so as not to create illusions of a future development of short-term earthquake prediction capabilities based on ULF magnetic precursors. At present, questions of fundamental importance should be: The ULF magnetic earthquake precursors are fact or fiction? Additional scientific and economical efforts in this field of research are justified?

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