MAGNETIC FIELD OBSERVATIONS CLOSE TO THE EPICENTER OF THE 2009 L'AQUILA EARTHQUAKE

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SUMMARY

On 6 April 2009 a seismic sequence culminated with the Mw6.3 main shock which heavily damaged the town of L'Aquila.

Here, we report the analysis of ULF magnetic field data from the Geomagnetic Observatory of L'Aquila during the period 2008-2009. Magnetic data are investigated by means of conventional techniques of polarization ratio and fractal analysis. In addition, total geomagnetic field data from the INGV Central Italy tectonomagnetic network were also investigated using the simple inter-station differentiation method. Our study does not show any anomalous signal that could be undoubtedly related to the seismic activity.

1. INTRODUCTION

The characteristics of the L'Aquila 2008-2009 seismic sequence are that the earthquakes were shallow and very close to the INGV Geomagnetic Observatory of L'Aquila. The epicentre of the main shock was only 6 km further from the observatory. These characteristics could justify the observation of possible seismogenic electromagnetic signals also providing an opportunity for a careful investigation of the reliability of the methodologies adopted in previous studies which have documented the observation of magnetic earthquake precursors. After April 2009, many papers retrospectively claimed the observation of pre-seismic electromagnetic signals up to several hundreds of kilometres from the epicentral area (see the references by Masci and Di Persio, 2012). On the contrary, other studies (e.g. Biagi et al., 2010; Villante et al., 2009) based on magnetic observations from the L'Aquila area did not found any electromagnetic precursory signal. Here are reported the results of the analysis of magnetic data from the INGV (Italian Istituto Nazionale di Geofisica e Vulcanologia) Geomagnetic Observatory of L'Aquila and from the Central Italy tectonomagnetic network.

2. ULF ANALYSIS

ULF Magnetic data (1 Hz sampling rate) from the Geomagnetic Observatory of L'Aquila are analyzed in the range of frequency [3–100] mHz by investigating the changes in the magnetic polarization ratio and the variations of the fractal characteristics of the geomagnetic field components (see Hayakawa et al., 1996, 1999). The time window [22:00–02:00] UT (LT=UT+1) has been chosen to minimize the background noise level. Figure 1 shows the geomagnetic field polarization ratio during the period 2008–2009 in four frequency bands. The lack of data in December 2008 is due to instrumental problems. The figure does not show any clear anomalous polarization ratio change that could be reasonably related to L'Aquila earthquakes. However, a slight increase of the polarization ratio can be seen in the lower frequencies between the last months of 2008 and the beginning of 2009 just before the 6 April main shock. Further analyses, not reported here, using geomagnetic data from previous years showed that this increase is related to an annual modulation of the polarization ratio, thus this increase cannot be explained in term of seismogenic emissions. In addition, magnetic data are also analyzed by mean of the "improved polarization analysis" proposed by Ida et al. (2008). Also in this case, there are no seismogenic signatures which could be related to the L'Aquila earthquake.

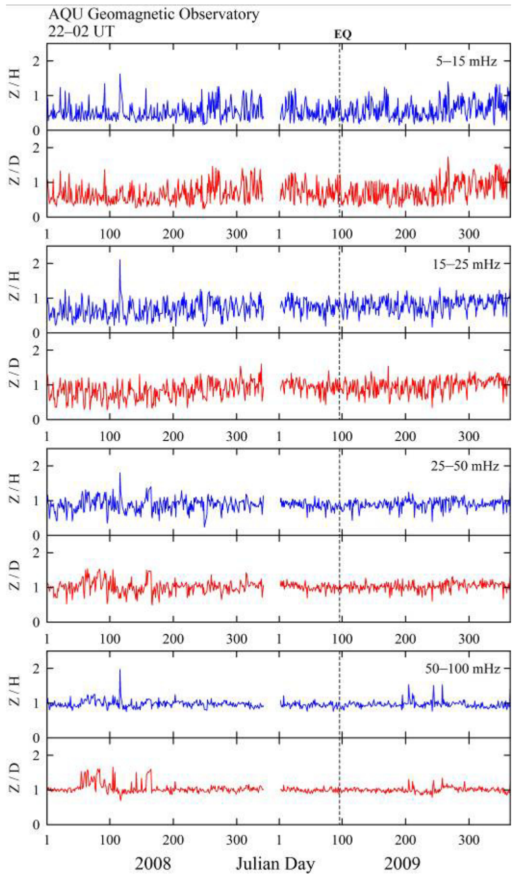

Figure 1 –Polarization ratio during 2008–2009 in four bands of frequency.EQ: Earthquake.

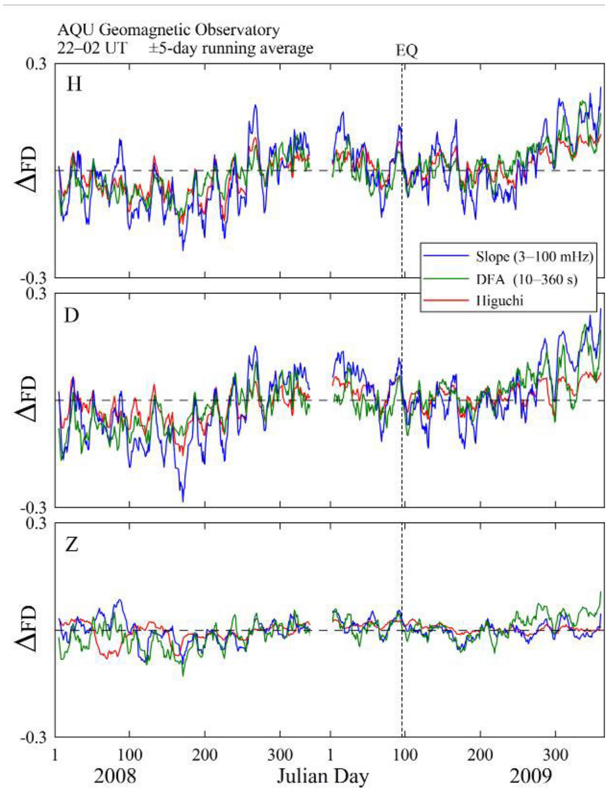

Figure 2 –Variation of the geomagnetic field fractal dimension with respect to the 2008–2009 average value. EQ: Earthquake.

The fractal dimension of the geomagnetic field components was calculated using the Slope, the Higuchi, and the DFA methods. In Figure 2 we report the FD variation (ΔFD) of the AQU geomagnetic field components with respect to the average value calculated in the period 2008–2009 (see Masci and Di Persio, 2012 for details). ΔFD is shown as ±5-day running average. The three methods provide similar results; ΔFD shows a ≈27-day modulation superimposed to a longer-term behaviour. This modulation is more evident in the horizontal components H and D of the geomagnetic field than in the vertical component Z, the latter being the component less influenced by magnetospheric and ionospheric disturbances. This characteristic suggests that the fractal dimension changes have mainly a magnetospheric origin caused by solar-terrestrial interaction. In summary, the fractal analysis does not show anomalies that could be related to the seismic activity. However, if we take into account the fractal dimension temporal evolution in the same manner as it has been done in previous studies, we note an increase of ΔFD which starts about the middle of March 2009. Later, just after the main shock, the fractal dimension decreases. All the components of the geomagnetic field show this behaviour. The FD increase which occurs just before the earthquake is more evident in Figure 3b where the Higuchi fractal dimension of the geomagnetic field H component, the temporal evolution of global geomagnetic index ΣKp, and the seismic activity (Ml) during the period July 2008–July 2009 are shown. We can also note that the ΔFD increase corresponds to the rise in the seismic activity during March 2009. As a matter of fact, Figure 3b shows that the ±5-day running average time-series of the Higuchi fractal dimension and ΣKp have a negative correlation during the entire period of time. In addition, the figure also shows that the FD increase which occurs before the main shock is closely related to a decrease in the geomagnetic activity. Thus, the possible correlation to the seismicity is not supported by the analysis. In summary, the simultaneous increase of FD and seismic activity is a coincidence. As expected (see Masci, 2011a), a similar correspondence also exists between the geomagnetic activity and the polarization ratio. Figure 3a shows this correspondence in the frequency band [5–15] mHz for the H component of the geomagnetic field.

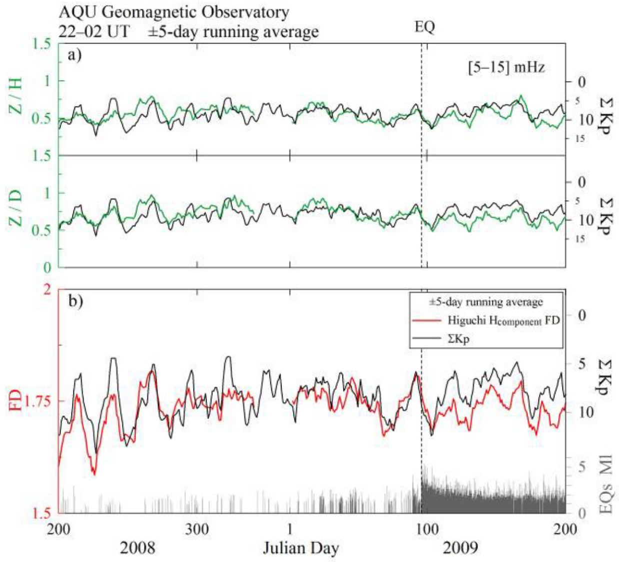

***Figure 3 –(a) Polarization ratio in the frequency band [5–15] mHz and (b) Higuchi fractal dimension of the geomagnetic field H component compared with the ΣKp time-series. The seismicity (Ml) of the L'Aquila area is reported as well. EQ: Earthquake*.**

3. TOTAL GEOMAGNETIC FIELD ANALYSIS

Several tectonomagnetic networks of total field magnetometers are in operation around the world. A well-known tectonomagnetic network is located along the San Andreas Fault in California. Even if the observations of co-seismic magnetic anomalies (up to few nT) are quite frequent, pre-seismic changes of the total geomagnetic field are uncommon. Johnston et al. (2006) maintain that during 25 years of observations along the San Andreas Fault (about 150 M>5.0 earthquakes) a clear 1nT pre-earthquake magnetic anomaly has only been observed once. The simplest method to isolate anomalous changes in the total magnetic field is calculating the differences of synchronously sampled measurements from pairs of stations located some kilometres apart. The differentiation procedure should remove the contributions from other sources, which are external (e.g. electric currents in the ionosphere and magnetosphere) and internal to the Earth (e.g. secular trend of internal origin due to the Earth's core electric currents). Any remaining signal could be attributed to local magnetization changes in the Earth's crust and to the tectonic activity.

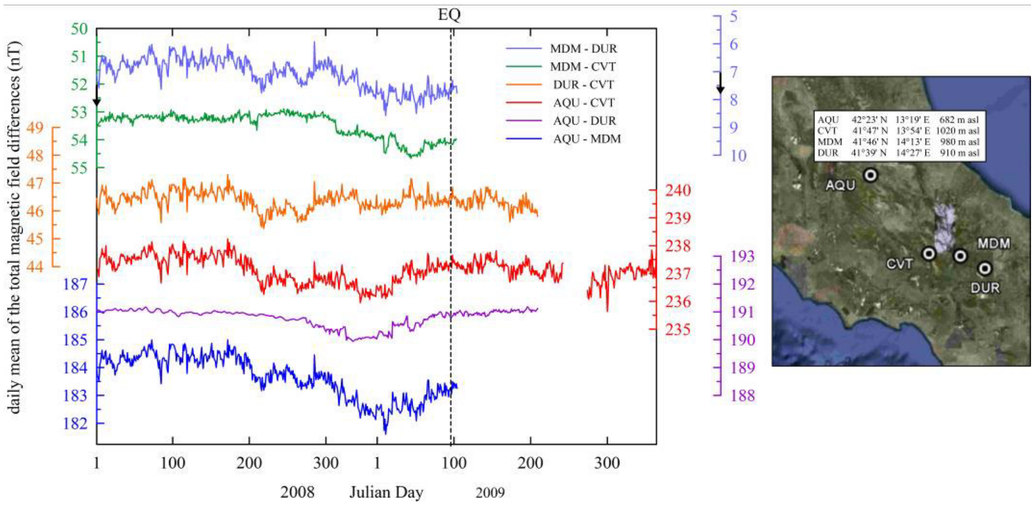

***Figure 4 –Daily means of the total magnetic field differences between pairs of stations of the INGV tectonomagnetic network. The location in Central Italy of the network stations is shown in the right part of the figure.EQ: Earthquake*.**

During the last two decades, a time-synchronized network of total field magnetometers has been in operation in Central Italy along the Apennine chain (see Masci et al., 2007 for details). In Figure 4 the daily mean of the differences between pairs of stations are reported. The figure does not show any magnetic anomaly that can be identified as precursor of the 6 April earthquake. In addition, also the expected co-seismic offset is not present. As the matter of fact, a long-term behaviour in the AQU-DUR time-series can be noted. More precisely, we see a slow decrease between the middle of 2008 and the beginning of 2009. Later, AQU-DUR increases during the period just before the main shock. This could suggest the possible presence of a local effect in the AQU data which could be considered a long-term seismogenic signature of 6 April earthquake. However, all the differences seem to show the same long-term behaviour, thus the behaviour of the AQU-DUR difference cannot be reasonably associated to the preparation process of the L'Aquila earthquakes.

4. CONCLUSIONS

Our study does not show anomalous signals that could be specifically related to the seismic activity. On the contrary, by means of the ΣKp index time-series we have found that during 2008-2009 the fractal dimension, as well the polarization ratio, show a close inverse correlation with the global geomagnetic activity. This correlation is also evident just before the 6 April main shock. In addition, total geomagnetic field analysis of the Central Italy tectonomagnetic network shows that no seismogenic pre-earthquake and co-seismic signals have been observed. In conclusion, within the limits of our analyses no earthquake-related signal can be identified. Our results support the conclusions of several studies (e.g. Masci, 2010, 2011a, 2011b, 2012a, 2012b, 2012c; Thomas, 2009) which have demonstrated the lack of any evident pre-earthquake seismogenic signatures in the fractal dimension, as well as in the polarization ratio, of the geomagnetic field for earthquakes which occurred at different latitudes, and having magnitudes that range between 4 and 9.

5. REFERENCES

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