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Comment on "Ultra low frequency (ULF) electromagnetic anomalies associated with large earthquakes in Java Island, Indonesia by using wavelet transform and detrended fluctuation analysis", by Febriani et al. (2014)

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Comment on Febriani et al. (2014)

F. Masci and J. N. Thomas

Abstract

We examine the recent report of Febriani et al. (2014) where the authors show changes in ULF magnetic field data prior to the *M*7.5 Tasikmalaya earthquake occurred south of Java, Indonesia, on 2 September 2009. Febriani et al. (2014) state that the magnetic changes they found may be related to the impending earthquake. We do not agree that the preearthquake magnetic changes shown in Febriani et al. (2014) are seismogenic. These magnetic changes, indeed, are too closely related to the global geomagnetic activity level to be regarded as being of seismic origin.

1 Introduction

Febriani et al. (2014) report changes in Ultra Low Frequencies (ULF: 0.001–10 Hz) geomagnetic field data a few weeks before the 2 September 2009 Tasikmalaya earthquake (*M*7.5, hypocentral depth 57 km) from a ground-based sensor at Pelabuhan Ratu, West Java, Indonesia, 135 km from the epicenter. This was the largest, and, according to the authors, the only earthquake preceded by anomalous magnetic changes, of twelve $M > 5$ earthquakes that occurred offshore south of Java from 1 September 2008 to 31 October 2010.

Febriani et al. (2014) suggest that the magnetic changes they reported may have been induced by an alleged preparatory phase of the earthquake. The idea that electromagnetic precursors appear before earthquakes is based on the assumption that earthquakes have a preparatory phase. That is, the earthquake initiates in a preparation zone (which size depends on the magnitude of the earthquake) where physical phenomena lead to the subsequent shock and to the possible appearance of precursory signals (see e.g. Dobrovolsky et al., 1979). However, there is no evidence that a preparatory phase of earthquakes really exists. Earthquakes, indeed, appear to be chaotic, scale-invariant phenomena controlled by the local mechanical properties of the fault whose geometry and frictional characteristics determine the starting and stopping of the rupture (see e.g. Geller, 1997; Kagan, 1997). Therefore, any small shock may grow into a stronger earthquake, and how big the quake will become is determined by how it is stopped, and not by how it starts. Consequently, the notion of the preparatory phase of earthquakes has no physical basis.

There are many papers (see the references section in Masci, 2010, 2011a, 2013) where the authors report pre-earthquake changes in ULF magnetic field data suggesting a possible relationship between the changes they identified and the impending earthquake. Conversely, recent reports (see e.g. Campbell, 2009; Masci, 2010, 2011a, b, 2012, 2013; Masci and De Luca, 2013; Masci and Thomas, 2013a, b, 2015; Thomas, 2009a, b) have shown that many of these preearthquake changes are, indeed, global-scale variations driven by the geomagnetic activity, or are generated by instrumental malfunction. These papers have cast into serious doubt the idea that ULF magnetic anomalies are convincing phenomena preceding large earthquakes. Therefore, at present ULF magnetic disturbances cannot be considered a promising candidate for developing earthquake prediction capabilities. We note that Febriani et al. (2014) ignore the findings of the recent reports where it has been shown that many ULF magnetic changes reported to occur before earthquakes are not precursors. They, in fact, refer to these invalid precursors as support of the search for precursory signatures of earthquake in ULF magnetic data (see Table S1 in the Supplement). In support of their findings, they also refer to an empirical relationship between the earthquake magnitude and the distance from the earthquake epicenter of the ULF station where the preearthquake anomaly has been detected (see Febriani et al., 2014; Fig. 10). In Fig. S1 of the Supplement, we show this relationship where we have highlighted with red dots alleged ULF magnetic precursory changes that have been proven invalid. In Table S2 we report the papers in which these precursors have been denied. Note that the empirical relationship in Fig. S1 was derived using not actual precursors. Thus, we conclude that Febriani et al. (2014) were motivated to search for precursory signals in magnetic data by reports of false precursors of earthquake.

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2 Comments

Febriani et al. (2014) analyze nighttime (16:00–21:00 UT) geomagnetic field data in the frequency range 10 ± 3 mHz. They calculate the ratio between the spectral intensity of vertical and horizontal magnetic field components, i.e., the so-called spectral density ratio. According to Febriani et al. (2014), magnetic data they analyzed are very disturbed by artificial noise even during nighttime. Thus, before performing the spectral analysis based on wavelet transform, they remove the intense transient signals. Then, they use the minimum energy method in an attempting to furtherly reduce the noise. More precisely, for each day, they divide four hours (16:30–20:30 UT) of magnetic data in eight 30 min intervals. Data before 16:30 UT and after 20:30 UT are excluded due to the edge effect of the wavelet transform. Then, the energy of the geomagnetic field vertical component Z (the component usually more disturbed by artificial noise) is calculated in each 30 min interval. Finally, the spectral density ratio is calculated in the interval where Z shows the minimum energy. Febriani et al. (2014) investigate the scaling proprieties of the geomagnetic field components by means of detrended fluctuation analysis (DFA) as well. DFA is a well-established method to extract quantitative time dynamic in time series. The DFA α exponent can be considered as indicator of the roughness of the time series: the higher is α, the smoother the time series (Peng et al., 1995). The α exponent may be related to the fractal dimension D by the relationship $D = 3 - \alpha$.

In Fig. 1 we show the spectral density ratio S_Z/S_Y (where Y is the east–west component of the geomagnetic field) and the DFA α exponent of the Z component, as reported by Febriani et al. (2014; Fig. 9) 30 days before and after the 2 September 2009. According to them, a magnetic anomaly is identified when the exponent α, and the ratio S_Z/S_Y exceed the threshold value of $(\overline{\alpha} - 2\sigma_\alpha)$ and $\left(\overline{S_Z/S_Y} + 2\sigma_{S_Z/S_Y}\right)$, respectively. Mean values and the corresponding σ are calculated over the 2 months period in Fig. 1. Based on their definition of an anomaly, Febriani et al. (2014) report to have found anomalous changes prior to the Tasikmalaya earthquake. More specifically, a few

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weeks before the earthquake, they note a decrease of the exponent α to which corresponds an increase of ratio S_Z/S_Y (see shadow areas in Fig. 1). They maintain that the decrease of α in correspondence with the increase of the spectral density ratio identifies a precursory signature of the Tasikmalaya earthquake in magnetic data.

We disagree with Febriani et al. (2014). First, there is no physical reason that magnetic anomalies, whatever might be their origin, are identified when the exponent α, and the spectral S_Z/S_Y exceed the threshold values they assumed. Then, their method for checking the geomagnetic conditions by means of the Dst index is not rigorous. We agree that geomagnetic activity should be considered as a key parameter in interpreting observed preearthquake ULF magnetic changes (see Balasis and Mandea, 2007). ULF disturbances from the ionosphere and magnetosphere, indeed, may lead researchers to interpret erroneously the origin of magnetic anomalies they identified (see e.g. Masci, 2010, 2011a). The 3 h global geomagnetic index Kp and the daily sum ΣKp are usually used as representative of the geomagnetic activity over planetary scale (Menvielle and Berthelier, 1991). Conversely, the Dst index that Febriani et al. (2014) use for checking the geomagnetic conditions is designed to monitoring the strength of the Equatorial Electroject, and it is usually used as indicator of the geomagnetic storm level and ring current intensification (Mayaud, 1980).

As expected, in Fig. 1 we note many decreases of α in correspondence of increases in the spectral density ratio. This inverse correspondence may be explained taking into account that the spectral density ratio, the DFA α exponent, and the fractal dimension D of the ULF geomagnetic field are sensitive to global trends in geomagnetic activity (see Masci, 2010, 2011a; Wanliss et al., 2014). Namely, when the geomagnetic activity decreases, the reduction of the geomagnetic field horizontal component is usually larger than the reduction of the vertical component, therefore the spectral density ratio increases. At the same time, the decrease of the geomagnetic activity indicates that the magnetosphere evolves toward a lower degree of organization (see e.g. Balasis et al., 2009). Thus, the fractal dimension of the geomagnetic field increases, while the DFA α exponent decreases. On the contrary, an increase of the geomagnetic activity induces

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a decrease of the spectral density ratio (because the increase in the geomagnetic field horizontal components is larger than the increase of the vertical component) and a decrease of the fractal dimension and an increase of α (because the magnetosphere evolves towards a higher degree of organization). Thus, we expect to find an inverse correspondence between ΣKp and the spectral density ratio and the fractal dimension of the geomagnetic field, and a direct correspondence between ΣKp and the α exponent. However, due to the global averaging used to calculate Kp, this correspondence is not expected always and everywhere. In this perspective, recent papers (see Masci, 2010, 2011a, 2013, and other papers reported in Tables S1 and S2) have demonstrated that many preearthquake ULF magnetic changes hypothesized to be seismogenic are, instead, part of global geomagnetic activity changes. In Fig. 1 we have used the same approach adopted in these papers by comparing the exponent α and the ratio S_Z/S_Y reported by Febriani et al. (2014) with the ΣKp index. In Fig. 1a, as expected, we note a close correspondence between α and ΣKp, both before and after the earthquake. A close inverse correspondence can be also seen in Fig. 1b between ΣKp and the ratio S_Z/S_Y calculated without the minimum energy method. However, we would like to point out that we should not expect to always find this correspondence, since: (i) as stated by Febriani et al. (2014) the high environmental noise in the geomagnetic field components was not attenuated enough after removing intense transient signals, (ii) several gaps are present in α and S_Z/S_Y time series, (iii) S_Z/S_Y shows many inexplicable zero values, (iv) α and S_Z/S_Y are calculated from local magnetic data, whereas, as already mentioned above, ΣKp is representative of daily averaged geomagnetic disturbances on planetary scale. Contrary to Fig. 1b, however, in Fig. 1c we see a lower correspondence between S_Z/S_Y calculated applying the minimum energy method and ΣKp. The lower correspondence may be explained considering that for each day Febriani et al. (2014) calculate the spectral density ratio, using the minimum energy method, in one of the eight 30 min intervals between 16:30 and 20:30 UT. Since ΣKp is representative of global daily averaged geomagnetic disturbance, by reducing the period of analysis, it is likely that the correspondence between geomagnetic data and ΣKp becomes less noticeable. Thus, the high dispersion of S_Z/S_Y values in Fig. 1c may be due to the short time interval (30 min) used in the spectral analysis, as well as because the S_Z/S_Y time series consists of values that are calculated in different 30 min intervals.

3 Conclusions

We have reviewed the findings of Febriani et al. (2014) that show preearthquake changes in magnetic field record before the $M7.5$ Tasikmalaya earthquake occurred on 2 September 2009 south of Java. We have shown that the changes they reported in the DFA α exponent of the geomagnetic field vertical component and the spectral density ratio S_Z/S_Y are too closely related with the geomagnetic ΣKp index to be considered of seismogenic origin. Thus, we conclude that the preearthquake magnetic changes reported by Febriani et al. (2014) is an effect of the global geomagnetic activity.

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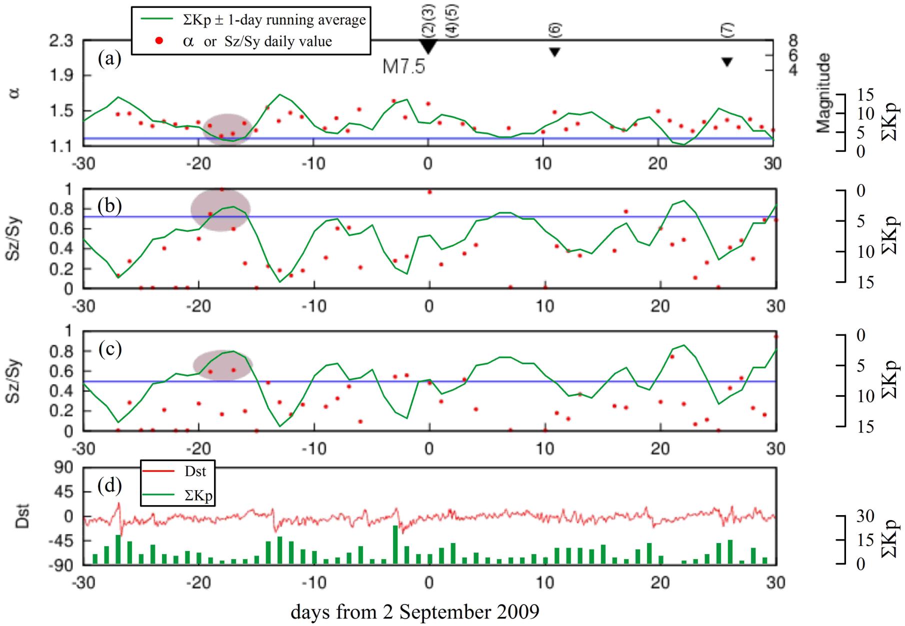

Figure 1. ULF analysis (10 ± 3 mHz) at the time of the 2 September 2009 Tasikmalaya earthquake as reported by Febriani et al. (2014; Fig. 9). Day = 0 is the day of the earthquake. **(a)** DFA α exponent of the magnetic field vertical Z component. The horizontal blue line refers to $\left(\overline{\alpha} - 2\sigma_{\alpha}\right)$. **(b)** and **(c)** spectral density ratio S_Z/S_Y calculated without and with the minimum energy method. The horizontal blue line refers to $\left(\overline{S_Z/S_Y} + 2\sigma_{S_Z/S_Y}\right)$. Shadow areas refer to the anomalies stated to be precursors of the 2 September Tasikmalaya earthquake by Febriani et al. (2014). **(d)** Dst index. ΣKp index time-series has been superimposed onto the original views. See text for details.