PRESEISMIC GEOMAGNETIC ANOMALOUS SIGNAL ASSOCIATED WITH MW8.3 CHILE EARTHQUAKE ON SEPTEMBER 16-TH, 2015

DRAGOȘ ARMAND STANICĂ, DUMITRU STANICĂ

"Sabba S. Ștefănescu" Institute of Geodynamics of the Romanian Academy,
19–21 Jean-Louis Calderon St.,020032 Bucharest, Romania

An earthquake of Mw8.3 hit the coastal zone of Coquimbo (Chile) on September 16th 2015, being also intensively felt along the Argentina border. To identify a possible inter-relation between the pre-seismic anomalous behavior of the geomagnetic polarization parameter (BPOL) and the Mw8.3 offshore Coquimbo (Chile) earthquake, generated on September 16th 2015, in this paper, we retrospectively analyzed the geomagnetic data collected in the 07 July – 21 September 2015 interval, via the Internet (www.intermagnet.com), at the Easter Island (IMP) and Pilar (PIL) geomagnetic observatories, placed in Chile and Argentina, respectively. Consequently, the average daily distribution of the polarization parameter (BPOL) and its standard deviation (STDEV) are performed in ULF range (0.001Hz-0083Hz) by using the FFT band-pass filter analysis. Further on, we investigate the singularity of the pre-seismic anomalous interval associated with the M_W8.3 earthquake by using a statistical analysis based on the standardized random variable equation expressed as: BPOL*=(X–Y)/W. The preseismic anomalous signal was identified with 14 days before the onset of the Mw8.3 offshore Coquimbo (Chile) earthquake.

Key words: Mw8.3 Chile earthquake, Bpol geomagnetic parameter, FFT band-pass filter analysis, ULF-preseismic anomalous geomagnetic signal identification.

1. INTRODUCTION

In the last two decades, the long-term real time ground–based geomagnetic observations done in the seismically active Vrancea zone (Stanica, D., and Stanica, D.A., 2009; 2011, Stanica D.A. *et al*., 2018, Stanica D.A. *et al*., 2020), together with supplementary studies regarding the Mw 9.0 Tohoku earthquake generated on March 11, 2011 (Stanica *et al*., 2015), the Mw 8.1 Chiapas earthquake on September 8, 2017 (Stanica and Stanica, 2019), Mw6.4 Coastal earthquake, Albania (Stanica and Stanica 2021) and the Mw.8.2 Alaska earthquake (D. A. Stanica, 2022) have enlarged our knowledge about the inter-relations among the pre-seismic anomalous geomagnetic phenomena and the final stage of the earthquakes' nucleation. Consequently, in this paper, we retrospectively analyzed the geomagnetic data collected in the 07 July – 21 September 2015 interval via the Internet (www.intermagnet.com), from the Easter Island (IMP) and Pilar (PIL) geomagnetic observatories, placed in Chile and Argentina, respectively (Fig. 1), with the aim to identify possible relationships between the pre-seismic anomalous behavior of the geomagnetic polarization parameter (BPOL) and the Mw8.3 earthquake that occurred offshore Coquimbo (Chile) on September 16th, 2015. Finally, the daily average distribution of the polarization parameter BPOL and its standard deviation (STDEV) are performed in ULF range (0.001Hz-0083Hz) by using the FFT band-pass filter analysis. After analyzing the value of the BPOL parameter obtained at both observatories, PIL being taken as reference one, we used a statistical analysis to identify, on September 2, 2015, a pre-seismic geomagnetic signature related to the Mw 8.3 Offshore Coquimbo earthquake, the lead time being 14 days before the impending earthquake (Fig. 1).

Figure 1 – Map of the Southern America with the Mw8.3earthquake placement on the Chile coastal zone (red star) and the geomagnetic observatories placements: IMP – Easter Island (blue sign) and PIL – Pilar (blue circle).

2. METHODOLOGY, DATA COLLECTION, PROCESSING AND ANALYZING

To identify a pre-seismic anomalous geomagnetic signature related to the Mw8.3 earthquake, it is necessary to obtain information about two factors:

a) Polarization parameter (BPOL):

For a given geoelectric structure, the vertical magnetic component (Bz) is a totally secondary field and it is produced essentially by the Bx horizontal magnetic components (orientated to the North) and By (orientated to the East) and, the polarization parameter expressed as:

$$BPOL\ (f) = Bz\ (f) / SQRT[Bx^2(f)+By^2(f)], \quad (1)$$

which should be time invariant in non-seismic conditions and it becomes unstable before the onset of the seismic event.

b) Strain effect-related to the pre-seismic geomagnetic signal identification:

Long range effect of strain-related to the pre-seismic geomagnetic signals is given by (Morgunov, Malzev, Tectonophysics 2007) relation:

$$R\ (km) = 10^{0.5M-0.27}, \quad (2)$$

R is epicentral distance and **M** is earthquake magnitude.

For the M8.3 Coquimbo earthquake the range effect of strain is: **R ~ 7586 km**.

In conformity with Relation (2), the strain effect of the Mw8.3 Chiapas earthquake may be felt at the distance **R ≈ 7600 km**, as in this particular case, the distance between IMP and the earthquake epicenter is about **3500 km** and, respectively, **1000 km** for PIL, so that the condition to identify a pre-seismic anomalous signature is fulfilled in both observatories.

DATA PROCCESING AND ANALYSIS

To carry out a pre-seismic anomalous signature associated with the M_W8.3 Chile earthquake**,** the following steps have been used:

a) An FFT band-pass filter analysis carried out in the frequency range 0.001Hz–0.0083Hz has been performed on the BPOL time series, for two successive time windows of 1024 samples, with 60% overlapping, on the entirely series of 1440 data points acquired each day at the both observatories (Fig.2).

The new time series obtained for the observatories (IMP and PIL) are used to calculate the daily average value of BPOL and its standard deviation (STDEV) in the July 06 – September 21, 2015 interval, and the results are presented in Fig.3 and Fig. 4.

b) To assess the singularity of the pre-seismic anomalous signal related to the M_W8.3earthquake, a statistical analysis based on the standardized random variable Equation (3) was performed:

$$BPOL^*=(X–Y)/W, \quad (3)$$

where:

- X is 5 days running average of BPOL (IMP) – BPOL(PIL) for a particular day;
- Y is 30 days running average of BPOL(IMP) – BPOL(PIL) before a particular day;
- W is 30 days running average of STDEV (IMP) – STDEV(PIL) before a particular day;
- BPOL*(IMP-PIL) time series emphasizes the threshold for anomaly using STDEV.

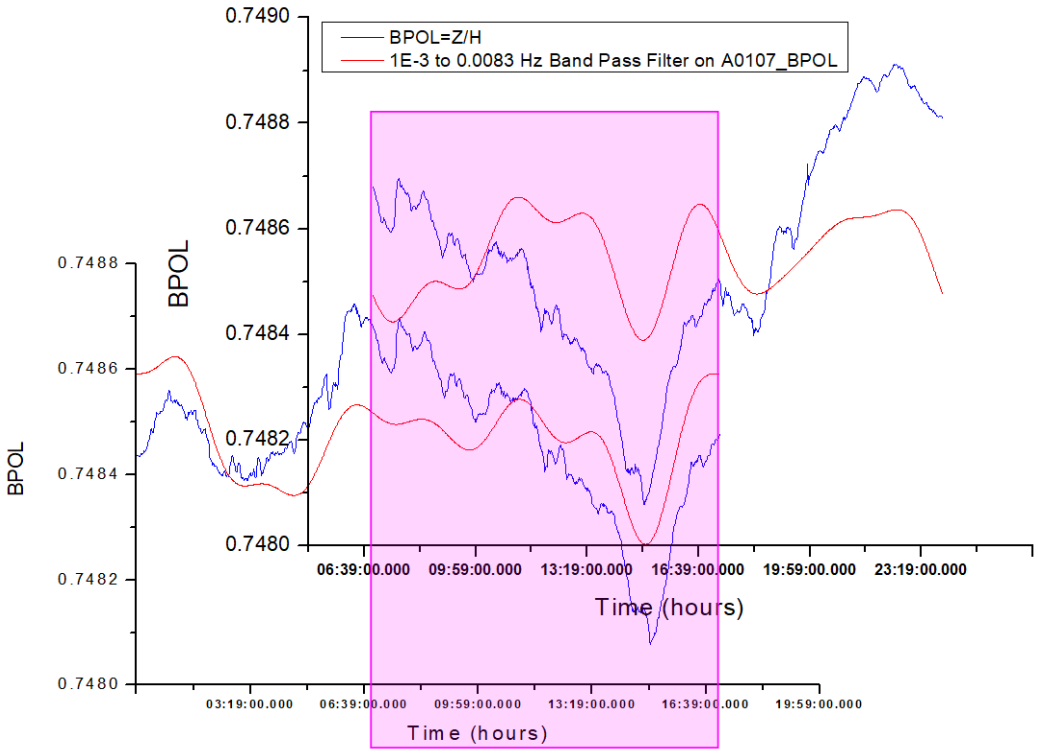

Figure 2 – FFT (Fast Fourier Transform) Band-pass filtering (red line) was applied on BPOL (geomagnetic polarization parameter) time series (blue line) in the frequency range 0.001Hz–0.0083Hz; for a window of 1024 samples carried out using Relation 1.

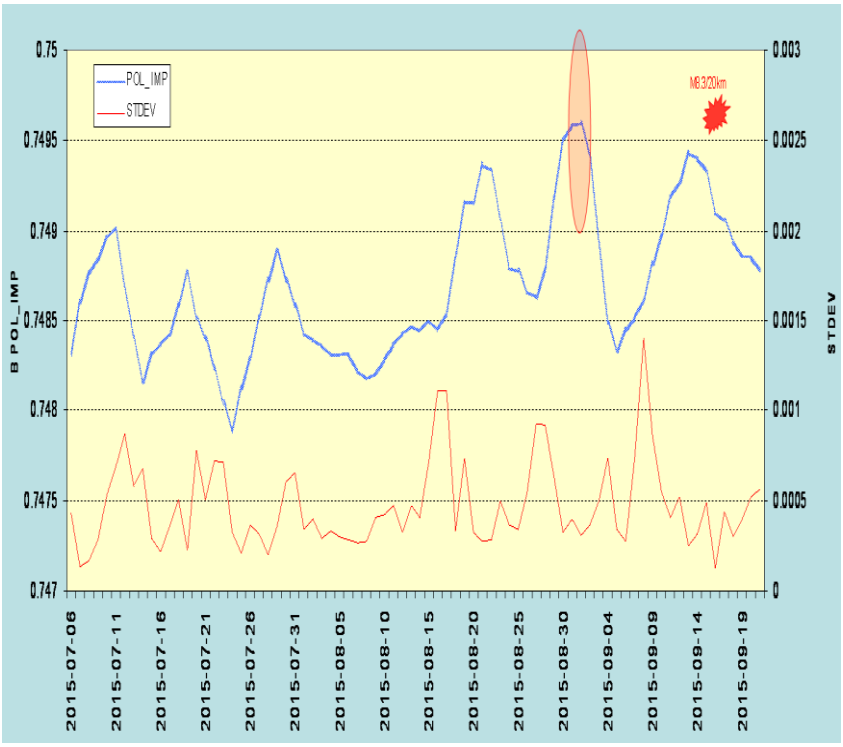

Figure 3 – Daily mean distribution of the BPOL parameter and its STDEV obtained for IMP observatory: red star indicates Mw8.3earthquake, on September 16, 2015; ratio 8.3/20km is magnitude/hypocenter; red ellipse emphasizes the pre-seismic geomagnetic signal.

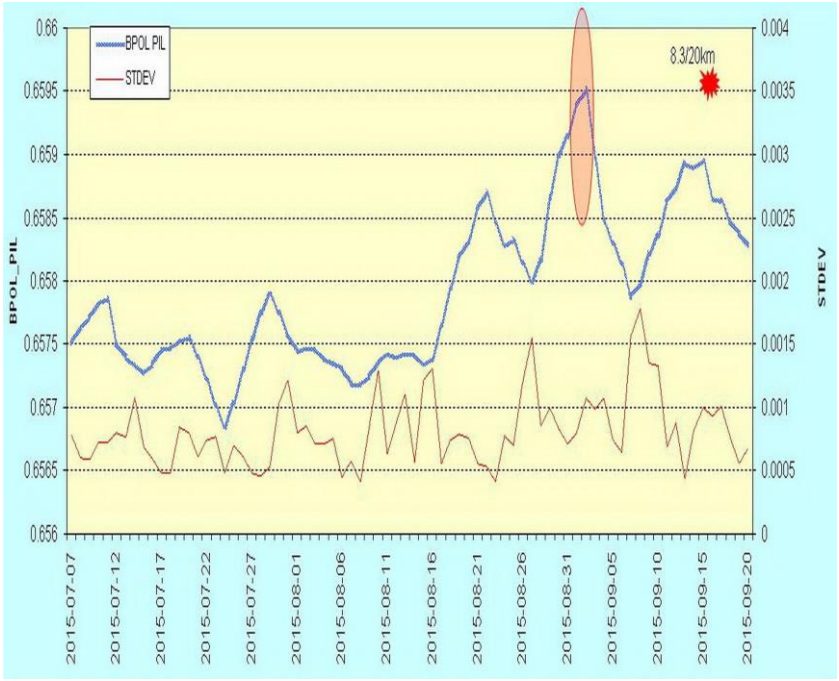

Figure 4 – Daily mean distribution of the BPOL parameter and its STDEV obtained at PIL observatory, red star indicates Mw8.3earthquake, on September 16, 2015; ratio 8.3/20km is magnitude/hypocenter; red ellipse emphasizes the pre-seismic geomagnetic signal.

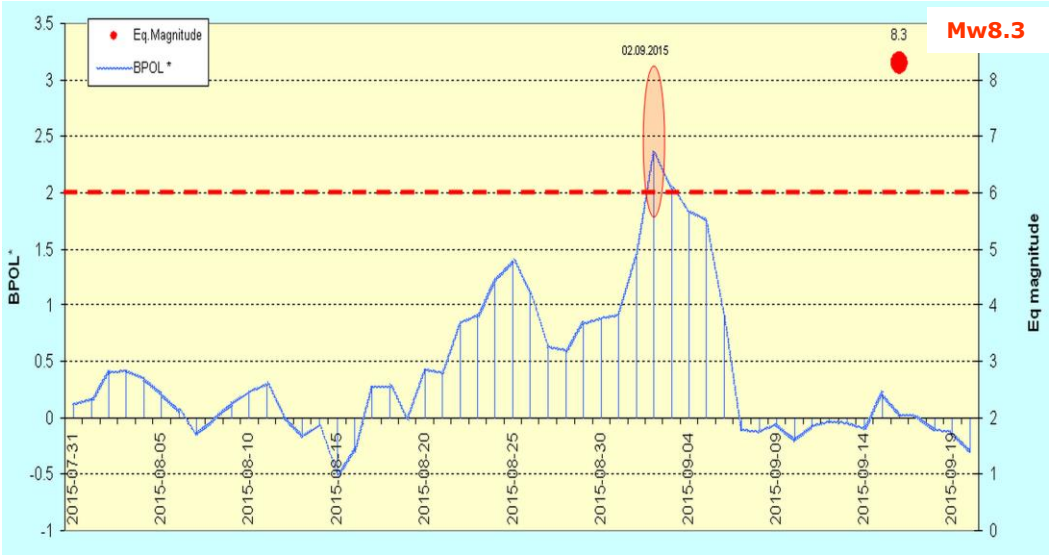

Figure 5 – Daily distribution of the parameter BPOL* on the interval August 1 – September 19, 2015 (blue line). Red full circle is Mw8.3earthquake, red ellipse is a pre-seismic anomalous signature of the Mw8.3 on September 2, 2015, red dashed line represents threshold for anomaly using STDEV.

CONCLUSIONS

In order to emphasize the possible interrelation between the pre-seismic geomagnetic signature and the Mw8.3 Chile earthquake, in this paper we have investigated the ULF geomagnetic data collected in the 06.07–20.09.2015 interval at the Easter Island (IMP) and Pilar (PIL) geomagnetic observatories, placed in Chile and Argentina, respectively. Thus, the daily average distributions of the BPOL(IMP) and BPOL(PIL), presented in Figures 3 and 4, were analyzed for the July–September, 2015 interval, both emphasizing on September 3, 2015 two very high amplitudes of the geomagnetic parameters (BPOL=0.659 for PIL and BPOL = 0749 for IMP), both being associated with the Mw8.3earthquake, suggesting the existence of a co-seismic effect.

The proposed methodology regarding the distribution of the geomagnetic polarization parameters BPOL and BPOL*, last one being obtained by using a standardized random variable equation (relation 3), provides adequate information to identify, starting with September 2, a peak level higher than 2 BPOL* (red dashed line in Fig. 5), the lead time being 14 days before the onset of the M8.3 offshore Coquimbo (Chile) earthquake (read ellipse).

Acknowledgements. The results presented in this paper are based on data collected at Geomagnetic Observatories Easter Island (IMP) and Pilar (PIL) that are placed in Chile and Argentina. We thank the national institutes that support them and the INTERMAGNET for promoting high standards of magnetic observatory practice (www.intermagnet.org).

REFERENCES

Morgunov V.A., Malzev S.A. (2007). A multiple fracture model of pre-seismic electromagnetic phenomena, Tectonophysics 431, 2007, pp. 61–72.

Stanica, D., and Stanica, D.A., 2009. Constraints on correlation between the anomalous behavior of electromagnetic normalized functions (ENF) and the intermediate depth seismic events occurred in Vrancea zone (Romania), Terr. Atmos. Ocean. Sci., vol.21, No. 4, 675–683, August 2010, doi:10.3319/TAO.2009.09.09.01(T).

Stanica D., Stanica D.A. (2011). Anomalous pre-seismic behaviour of the electromagnetic normalized functions related to the intermediate depth earthquakes occurred in Vrancea zone, Romania, Nat. Hazards Earth Syst. Sci., 11, pp. 3151–3156, doi: 10.5194/nhess-11-3151, 2011.

Stanica D.A., Stanica D., Vladimirescu N. (2015). Long-range anomalous electromagnetic effect related to M9 Great Tohoku earthquake. *Earth Science.* Vol.4x, No.1, pp.31–38. 2015, doi:10.11648/j.earth.20150401.13.

Stanica D.A., Stanica D., Blecki J., Ernst T., Jozwiak W., Slominski J. (2018). Pre-seismic geomagnetic and

ionosphere signatures related to Mw5.7earthquake occurred in Vrancea zone on September 24, 2016, pp.167–177, https//doi.org/10.1007/s11600-018-0115-4.

Stanica D.A., Stanica D. (2019). ULF Pre-seismic geomagnetic anomalous signal related to Mw8.1 offshore Chiapas earthquake, Mexico on 8 September 2019, Entropy 2019, 21, 29; pp.1–11, https://doi:org/10.3390/e21010029.

Stanica D. A., Stanica D., Valeca M., Iordache S., (2020). Electromagnetic contribution to the resilience improvement against the Vrancea intermediate depth earthquake, Romania. ANNALS of GEOPHYSICS, 63, 5, PA551, 2020: Doi: https://doi.org/10.4401/ag-8096

Stanica D.A., Stanica D. (2021). Possible correlations between the ULF geomagnetic signature and Mw6.4 Coastal earthquake, Albania, on 26 November 2019, Entropy 2021, 23, 233. https://doi.org/10.3390/e2302233.

Stanica D., Stanica D.A. (2021). Pre-seismic geomagnetic anomalous signature related to Mw.7.0 earthquake generated in the northern coastal zone of Samos Island-Greece on October 30, 2020, EGU21-1078, https://doi.org/10.5194/egusphere-egu21-1078.

Stanica D.A. (2022). Anomalous geomagnetic signal emphasized before the Mw8.2Coastal Alaska earthquake, occurred on 29July 202, Entropy 2022,24, 274. https://doi.org/10.3390/e24020274.