Earthquakes unrelated to natural geomagnetic activity: A North Korean case

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Abstract: The 24/7 monitoring of radio anomalies at a monitoring station in Rome, Italy, starting from 2009, has shown that potentially destructive earthquakes, generally with a magnitude greater than M6, but also above M5+, have all been preceded by characteristic geomagnetic anomalies. These variations have been linked to geophysical activity and, in particular, with phenomena preceding strong earthquakes. The recent news given by the media and on the web of an induced seism in North Korea offered an opportunity to check on the reliability of the detection method. Analysis of data recorded by the Rome monitoring station has shown that the seism in North Korea was not preceded by anomalies linked to precursory signals, a fact confirmed by other observatories around the globe. The results of this study underlined two points, the first being the reliability of the detection of radio anomalies associable with potentially destructive seisms, the second that the Method can prove useful to monitor the occurrence of man-made earthquakes.

Keywords: *induced seisms, radio-anomalies, pre-seismic signals, ELF, potentially destructive earthquakes*

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INTRODUCTION

The problem of induced seismicity began to be studied last century, with the devastating earthquake that occurred near the Koyna Dam in India in 1967 (Gupta, 2002; Smirnov et al., 2014). The rubble dam, built in an area potentially not subject to seismicity, ended up causing an M6.7 earthquake after the construction of the reservoir. The devastating earthquake and the moderate seismicity that preceded it gave rise to research efforts which, over time, confirmed the potential link between the reservoir and successive seismicity. In those same years, in Denver, an earthquake with a magnitude of M4.5 struck an area not normally affected by seismicity, intensified after the pumping of liquids into the ground which, according to geologists, upset the equilibrium of a geological fault (Hsieh and Bredehoeft, 1981). Examples of induced seismicity caused by RIS (James, 2000; James, 2014), extraction of oil, gas, and minerals, anthropic activities and atomic testing, are well known in the literature (Horton, 2012; Nicholson et al., 1988; Aki et al., 1974). As for nuclear tests, studies have been carried out by various authors (Bolt, 1977; Boucher et al., 1969; Hamilton and Healy, 1969; Nikolaev et al., 1995) and the seism recorded in North Korea recalls, in its type, another two experiments made on 9 October 2006 linked to an earthquake with a magnitude of 4.2 on the Richter scale, that occurred below sea level approximately 385 kilometres from Pyongyang.

The seism of 6 January 2016 with a magnitude of M5.1 that occurred 19 kilometres from Sungjibaegam (**Fig. 1**), was very similar in terms of energy to the one that occurred on 12 February 2013 in the same area, offering an opportunity to compare the electromagnetic signals that preceded the two events. Neither earthquake was preceded by significant signals or anomalies characteristic of seismic indicators, such as the Seismic Geomagnetic Precursors and radio anomalies successfully employed for seisms with a magnitude equal to or greater than M6.0 on a global scale (Straser, 2011; Straser 2012; Cataldi et al., 2013).

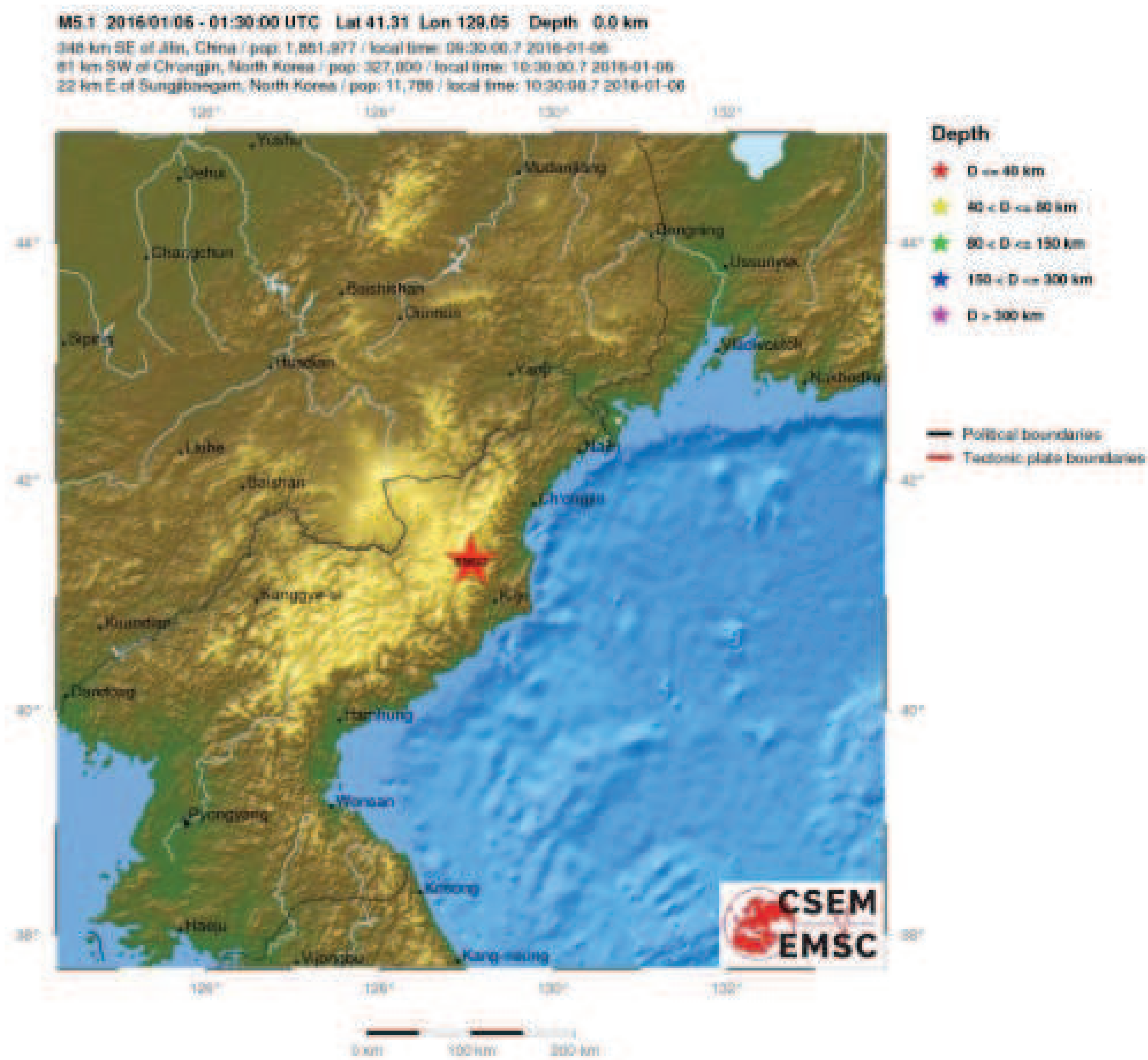

Fig. 1. Index Map, seismic event in North Korea recorded by the EMSC CSEM network (www.emsc-csem.org).

Characteristics of Seismic Geomagnetic Precursors or SGP

Seismic Geomagnetic Precursors or SGP are variations in the Earth's geomagnetic field, (geomagnetic anomalies) associated with a variation in solar activity, which precede strong earthquakes (earthquakes with a magnitude of at least 6Mw or M6+). According to data from monitoring the SELF-ELF band, the spectrographic characteristics of these radio emissions are identifiable as those typical of a geomagnetic perturbation occurring after an increase in solar activity, and as clear generic increases in the Earth's geomagnetic field at a frequency from <3Hz to ~10-15Hz, with an intensity directly proportional to their wavelength. The same anomalies, if observed using a fluxgate magnetometer that produces magnetograms, appear as intense variations in the geomagnetic field following an increase in solar activity.

The first instrumental observation of an SGP was made by the authors in 2010, but only in more recent years has it been possible to correlate these emissions to solar activity. By analysing data on M6+ global seismic activity and data from electromagnetic monitoring of the SELF/ELF band between 1 January 2012 and 31 December 2012, it emerged that all the M6+ earthquakes that occurred on a global scale were preceded by an increase in the natural electromagnetic background between <3Hz and ~10-15Hz. Taking as a reference the maximum intensity recorded of the electromagnetic anomaly (SGP), it has been possible to calculate the temporal difference between this and an M6+ seism: the average temporal difference recorded is ~598 minutes (~9 hours). The minimum temporal difference recorded is 1 minute (M6.4 Balleny Island earthquake, 9 October 2012); the maximum temporal difference recorded is 2241 minutes (M6.0 Kuril

Islands earthquake, 9 September 2012).

Variations in the geomagnetic field associated with seismic events

Variations in the natural electromagnetic field in the SELF/ELF band were observed preceding 5 earthquakes with a magnitude >M6.0 in Mexico from 1999–2001. Variations in the geomagnetic field with a frequency < 3Hz were observed before earthquakes in: Armenia, Spitak (1988 December 8, M6.9); USA, California, Loma Pietra (1989 October 18, M7.1); Guam (1993 August 8, M8.0); Japan, Izu Peninsula (2000 July 1, M6.4). In 1964, a dramatic perturbation of the natural magnetic field with a frequency ≤ 10Hz was recorded before the M9.2 seism that occurred at Kodiak, Alaska. Radio emissions with a frequency < 3Hz were observed before the M7.1 seism that occurred at Hotan in the Xinjiang province of China on October 19, 1996. Electromagnetic perturbations with a frequency in the range of Pc3 geomagnetic pulsation (10-40s) were observed before the strong M6.4 seism that occurred on the Island of Taiwan, China, on December 19, 2009. A study carried out from April 1997 to March 2002 by the RIKEN/UEC-NASDA scientific group, found the existence of electromagnetic anomalies in the SELF band before M6+ earthquakes. Strong radio emissions in the ELF band with a frequency of 3-10Hz were observed before the strong M8.0 seism that occurred in Wenchuan County, China, on 12 May 2008 (Li et al., 2013). Electromagnetic variations in the 0-15Hz band preceded the M9.0 earthquake that occurred in Samoa on 29 September 2009. Electromagnetic emissions in the 0-20Hz band were observed before the M7.0 seism that occurred in Haiti on 12 January 2010. Variations in the electromagnetic field between 0.25 e 0.5Hz were observed before seismic events in Central Mexico from 2007 to 2009. Radio emissions in the SELF-ELF band were observed before the M5.5 seism that occurred in Bovec, Slovenia, on 12 July 2004. Intense variations in the geomagnetic field (including the appearance of geomagnetic micropulsations) preceded the activity of the Popocatépetl Volcano, Mexico, from March–July, 2005. Radio emissions with a frequency between 10.2 and 11.1mHz and between 13.6 and 14.5mHz (SELF band) preceded seismic activity in Central Mexico from 1999 to 2001(Kotsarenko et al., 2004).

Geomagnetic anomalies

The new method of seismic prediction of M6+ earthquakes that occur on a global scale was developed by the authors through a correlation study (which is still in progress) started in 2012 and currently (until March 15, 2016) consider 579 M6+ seismic events occurred on a global scale, practically all M6 + earthquakes that occurred between January 1, 2012 and March 15, 2016. The study allowed us to understand that all M6+ earthquakes that occur on a global scale are always preceded by an increase of solar activity and, more precisely, by an increase of the proton density of the interplanetary medium "near Earth" that is highlighted averagely points out that on average 137.8 hours before the earthquake. Following the proton density increase are seeing also various types of geomagnetic phenomena that are produced by the interaction between the solar wind and the Earth's magnetosphere that have different characteristics respect to the Sq variation (geomagnetic variation that occurs during solar quiet). In the hours that preceded the artificially induced earthquakes, instead, the variation of geomagnetic field followed the normal daily variation, in relation to space weather conditions, and have not been registered electromagnetic anomalies on a global scale caused by the detonation of nuclear warheads. The fact that before the earthquake produced as a result of nuclear detonations the geomagnetic activity did not present significant variations, indirectly confirms the observations that the authors have made since 2012 and that is that the M6+ seismic activity is always related to a variation of a solar activity and geomagnetic activity and is not related to induced earthquakes. The geomagnetic anomalies studied by the authors have been observed to precede strong earthquakes (M6 +) occurring on a global scale and, just by definition, are caused by an increase of solar activity and are not caused by local phenomena. In literature there are thousands of scientific studies that have analyzed the pre-seismic radio emissions produced in the focal zone of the earthquake, and many theories have been proposed to explain their formation (creation of microcracks, electronic currents, etc), but this type of emissions, precisely for their characteristics and to the characteristics of the vehicles in which they propagate, they cannot be confused with the signals of geomagnetic nature which, among other things, are monitored from outer space and from the Earth's surface. Currently, throughout the world, are operative more than 20 scientific projects that deal with studying the seismic precursors. Most of these have focused on the pre-seismic radio emissions of ionospheric nature and epicentral radio emissions, i.e. on local radio emissions, but does not exist a global or “non-local” scientific study project of seismic precursors if not the one represented by the authors of this paper, considering also that the first studies of the authors in this field of research began in 2011.

Solar activity and global seismic activity

Evidence on the influence that solar activity determines on seismic activity have been sought by many scientists beginning from the years 70's (Anagnostopoulos et al., 2010; Simpson, 1968). The proposals concerned:

- flow of protons emitted by the Sun (SPE and SEP) (Velinov, 1975);
- high-speed solar wind (HSSW) expelled from coronal holes (Odintsov et al., 2006);
- solar coronal mass ejections (CMEs) (Odintsov et al., 2006);
- oscillations of the magnetopause caused by an increase of the dynamic pressure of the solar wind (Makarova and Shirochkov, 1999) (Makarova and Shirochkov, 1999).

The solar coronal mass ejections (CMEs) have been correlated to high intensity seismic events during solar maximum; while the high-speed solar wind (HSSW) has been related to high intensity seismic events during the solar minimum (Odintsov et al., 2006; Jusoh and Yumoto, 2011); Furthermore it was found that the number of earthquakes between magnitude (Mw) 3.3 and 9.9 that occur on a global scale increases when increase the number of HSSW events.

The same correlation was observed between the increase of energy and dynamic pressure of the solar wind and seismic events (Jusoh et al., 2012).

There are various hypotheses about how the solar wind impact on the magnetosphere can generate an earthquake (Anagnostopoulos et al., 2010):

- electrical power supplied to the Earth during a geomagnetic storm is converted into mechanical energy through the phenomenon of piezoelectricity, the electrokinetic or other mechanical-electrical effects that overlap mechanical stress accumulated in a certain fault (Sobolev et al., 1998);
- variation of the atmospheric circulation by the Sun that generates a variation of the atmospheric pressure on a large scale (Odintsov et al., 2006) (Bucha and Bucha, 1998);
- generation of gravitational waves by auroral electroject after the arrival of high-speed solar wind (HSSW), (Prikryl et al., 2003)

Formation of an electroosmotic flow in the crust induced by a geomagnetic storm that can generate a porous abnormal pressure in the rocks that is able to activate the tectonic event (Kormiltsev et al., 2002).

Method used to monitor the geomagnetic field

The Method used to monitor the geomagnetic field by the authors to carry out their correlation study is based on the use of analogue radio receivers equipped with ultra-low-noise high-speed precision operational-amplifiers that operate efficiently with extremely low electronic noise in the following bands: SELF (<3Hz), ELF (3-30Hz), SLF (30-300Hz), ULF (300-3000Hz), VLF (3-30kHz) and LF (30-300kHz) through the use of wire-loop antennas and antennas that are sensitive to magnetic fields (bobbins) aligned according to the vectorial components of the geomagnetic field (Cataldi and Cataldi, 2013). The data were recorded at the LTPA Observer Project monitoring station, Radio Emissions Project, Albano Laziale (Rome), Italy.

DISCUSSION

1 - Comparison between the M5.1 earthquakes in North Korea in 2013 and 2015

1) 2013 earthquake
The seism, with a magnitude of M5.1, occurred during a general period of geomagnetic quiescence (**Fig. 2**) even if ISWA data reported a CME event that reached the Earth at around 08:00 on the same day that the Korean seism occurred. From this point of view, the data from the Tromsø observatory leave no room for doubt. The proton density of the solar wind was dropping after a major peak recorded on 8 February 2013. However, this increase can be correlated to M6+ seismic events on 10 February, with the Kp maximum at 2,

recorded on 9 and 11 February 2013. Moreover, on the proton curve preceding the seism there are no signs of an increase due to the CME. The speed of the solar wind was observed to be at base levels not correlated to disastrous earthquakes (Straser et al., 2015). The most significant variations can be seen in the magnetogram from Tromsø and correspond to the normal Sq curve recorded at those times.

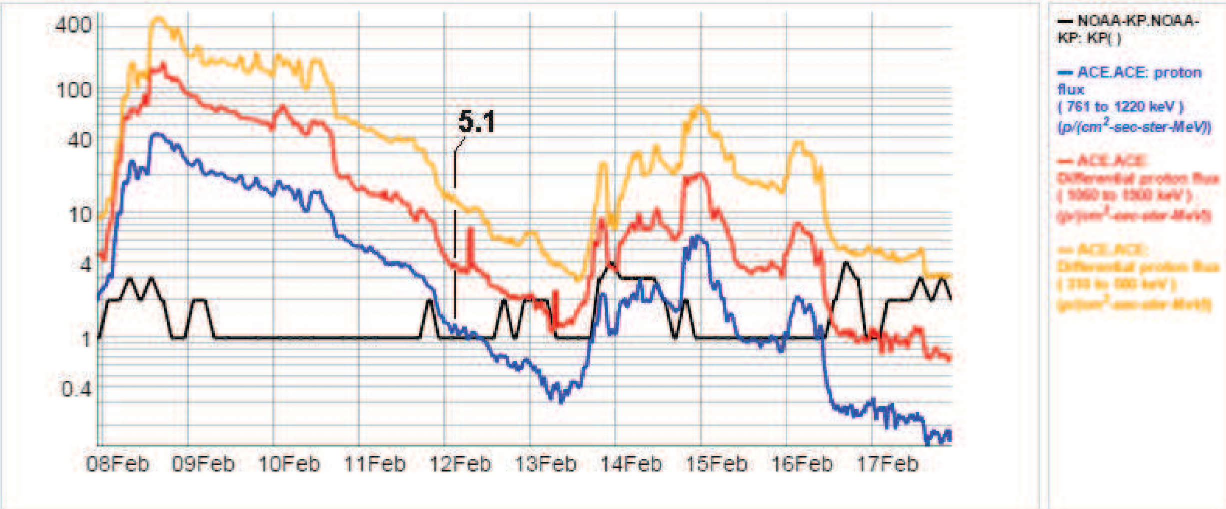

Fig. 2. Diagram created by the authors that highlights the absence of electromagnetic anomalies linked to the 5.1 seismic event.

2) 2015 earthquake

The spectrogram recorded by the Radio Emissions Project on 6 January 2016, relating to the M5.1 seism induced in North Korea, shows the total lack of electromagnetic signals in the SELF-ELF band around the temporal indicator of the earthquake.

In **Fig. 3** can be seen an expansion of the electromagnetic spectrum where it is normal to observe increases in the natural geomagnetic background with reference to seismic events of a certain intensity. In this case, these signals were totally absent, which in this context is anomalous, given that all natural seisms are always preceded and followed by electromagnetic emissions close to the time of the telluric event. These are determined both by natural emissions due to fragmentation of the rocks and to natural emissions deriving from the action of terrestrial geomagnetism. The total lack of these signals is an indicator that the seism cannot have been natural, i.e. determined by natural geological mechanisms.

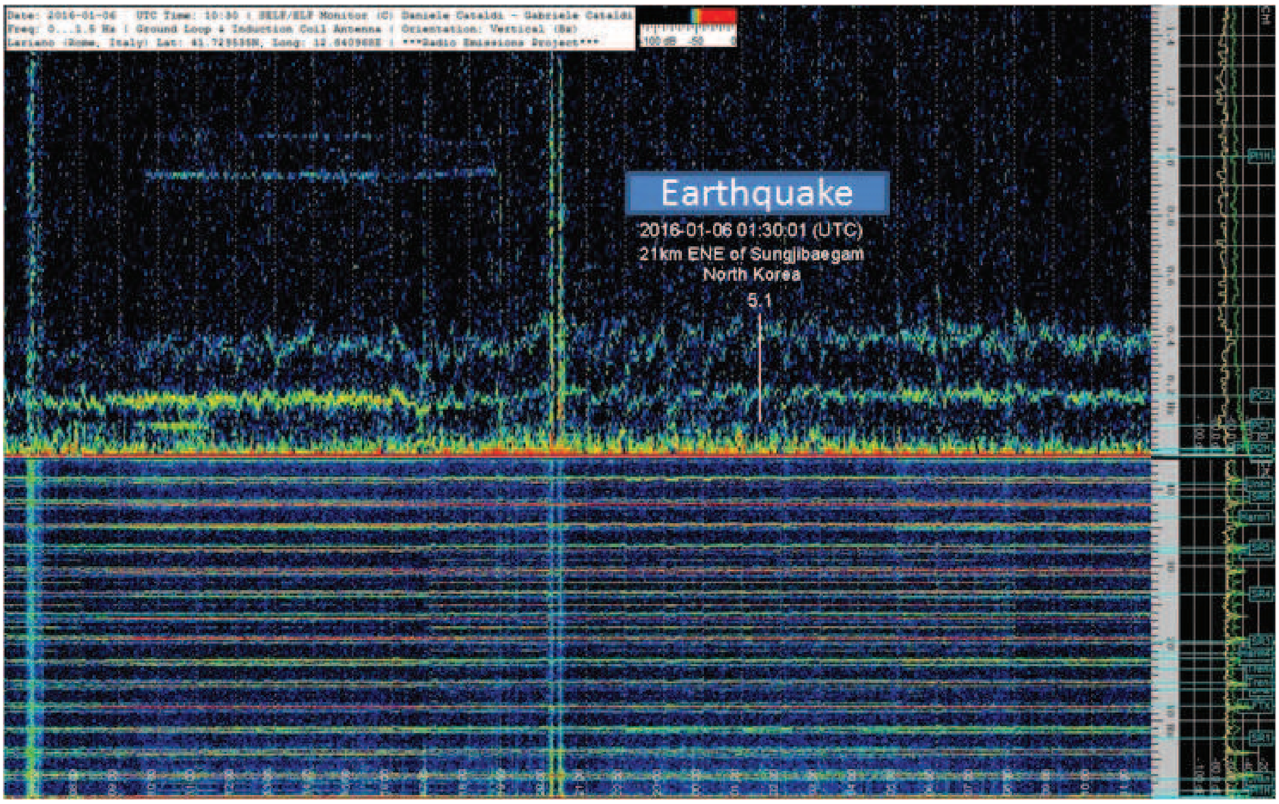

Fig. 3. Diagram by the LTPA Observer Project monitoring station, Radio Emissions Project, Albano Laziale (Rome), Italy. There is no interference before, during or after the seismic event.

2 - Characteristics of natural earthquakes: examples of seisms in Bolivia on 14 January 2016 and in Alaska on 24 January 2016.

1) Alaska, 24 January 2016

The spectrogram (**Fig. 4**) shows the normal geomagnetic alterations along with the natural preseismic signals of the telluric event that occurred in Alaska on 24 January 2016. The signals that can be seen were generated by disturbances of an electromagnetic type.

The emissions are clearly recognizable against the natural background, which appears darker and devoid of emissions of a particular intensity.

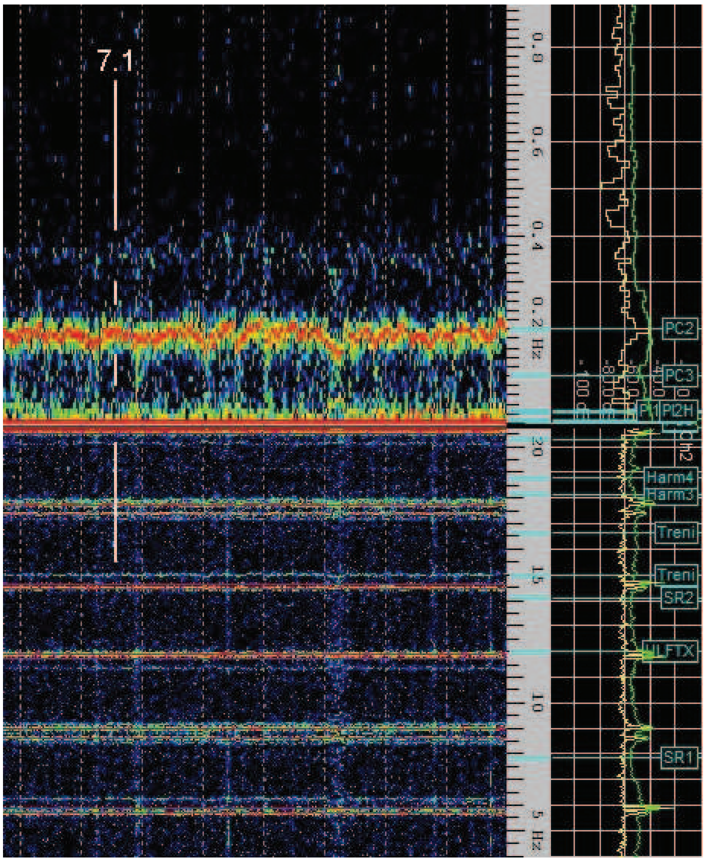

Fig. 4. Diagram by the LTPA Observer Project monitoring station showing in red the interference before and after the seism in the 0.2Hz frequency band.

2) Bolivia 14 January 2016

The double seism in Bolivia, which occurred on 14 January 2016, measuring M6.1 and M6.7, indicates, as others do, the interference detected before the seismic shocks on a global scale with a magnitude equal to or greater than M6.0+ (**Fig. 5**). In this case too, as in the Alaskan earthquake, the periseismic signals typical of natural telluric phenomena can be seen; in addition there is a geomagnetic increase in the natural background that accompanied and followed the two seisms after the mainshock. In this case too, the periseismic signals typical of natural telluric phenomena can be seen, albeit faintly.

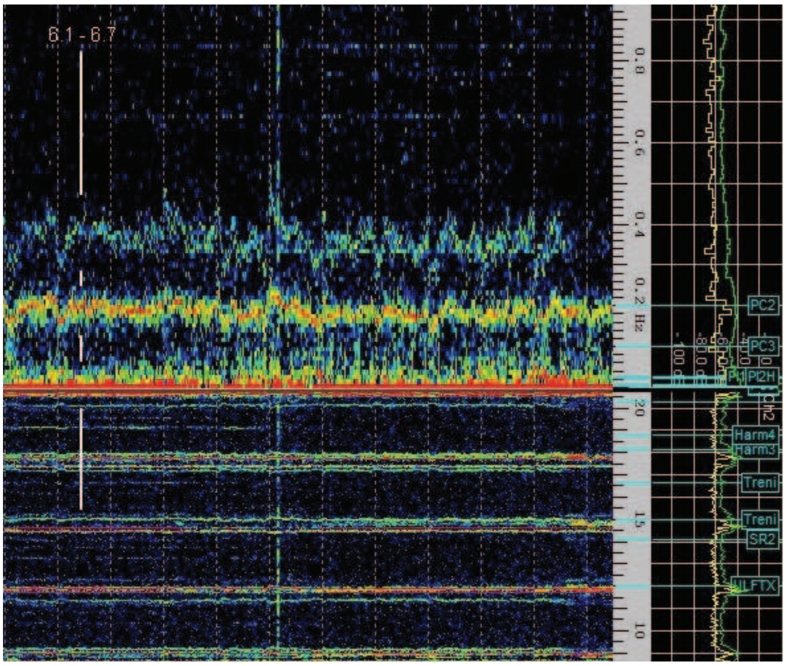

Fig. 5. Diagram showing radio anomalies in the 0.2Hz frequency band for the 6.1 and 6.7 seisms.

CONCLUSION

A comparison between the two North Korean earthquakes, both with a magnitude of M5.1, that occurred in 2013 and 2015, show elements in common in terms of strength, epicenter and absence of pre-seismic signals, as recorded by the LTPA Observer Project monitoring station, Radio Emissions Project, Albano Laziale (Rome), Italy. The absence of the radio-anomalies that precede earthquakes on a global scale indicate that the seism could have been triggered by a man-made explosion underground. On the other side of the coin, the North Korean cases confirm the validity of the Method for detecting natural seisms on a global scale, applicable both to seisms with a magnitude equal to or greater than M6, and earthquakes with a magnitude greater than M5.

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References

Abdurakhmanov A.I., Firstov, L.P. and Shirokov, V.A., 1976. Possible connection of volcanic eruptions with 11-year cyclicality of solar activity. In the book *Bulletin of Volcanic Stations*, Science, no. 52, p. 3-10.

Aki, K., Bouchon, M. and Reasenberg, P., 1974. Seismic source function for an underground nuclear explosion. *Bulletin of the Seismological Society of America,* v. 64, no. 1, p. 131-148.

Anagnostopoulos, G., Papandreou, A. and Antoniou, P., 2010. Solar wind triggering of geomagnetic disturbances and strong (M>6.8) earthquakes during the November – December 2004 period. *Demokritos University of Thrace, Space Research Laboratory*, 67100 Xanthi, Greece. Cornell University Library.

Bolt, B.A., 1977. Constancy of *P* travel times from Nevada explosions to Oroville dam station 1970-1976. *Bulletin of the Seismological Society of America February,* v. 67, p. 27-32.

Boucher, G., Ryall, A. and Jones, A.E., 1969. Earthquakes associated with underground nuclear explosions. *Journal of Geophysical Research*, v. 74, no. 15, p. 3808-3820.

Bucha, V. and Bucha Jr, V., 1998. Geomagnetic forcing of changes in climate and in the atmospheric circulation. *J. Atmos. Sol-Terr. Phys*. v. 60, no. 2, p. 145–169.

Cataldi, G. and Cataldi, D., 2013. Reception of natural radio emissions in the ELF Band. *INSPIRE Journal,* no. 20, Spring Summer.

Cataldi, G., Cataldi, D. and Straser, V., 2013. Variations of terrestrial geomagnetic activity correlated to M6+ Global seismic activity, EGU (European Geosciences Union) 2013, General Assembly, *Geophysical Research Abstracts,* vol. 15. Vienna, Austria. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

Duma, G., 2007. Earthquake activity controlled by the regular induced telluric currents, *Istituto centrale per la meteorologia e geodinamica, dipartimento di Geofisica*, gerald.duma@zamg.ac.at, Hohe Warte 38, A-1190 Vienna, Austria.

Gupta, H.K., 2002. A review of recent studies of triggered earthquakes by artificial water reservoirs with special emphasis on earthquakes in Koyna, India. *Earth-Science Reviews*, v. 58, p. 279–310.

Guschenko, N.I., 1985. Cyclicality of eruptions. Volcanology and seismology, no. 2, p. 27-48.

Hamilton, R.M. and Healy, J.H., 1969. Aftershocks of the Benham nuclear explosion. *Bulletin of the Seismological Society of America,* v. 59, no. 6, p. 2271-2281.

Horton, S., 2012. Disposal of hydrofracking waste water fluid by injection into subsurface aquifers triggers earthquake swarm in Central Arkansas with potential for damaging earthquake. *Seismological Research Letters,* v. 83, no. 2, p. 250–260.

Hsieh, P.A. and Bredehoeft, J.D., 1981. A reservoir analysis of the Denver earthquakes: A case of induced seismicity. *Journal of Geophysical Research,* v. 86, no. 2, p. 903–920.

Khain, V.E. and Khalilov, E.N., 2008. About possible influence of solar activity upon seismic and volcanic activities: long-term forecast. *Transactions of the International Academy of Science H & E*, v. 3. 2007/2008, ISSN 2070-0334.

Kormiltsev, V.V., Kostrov, N.P., Ratushnyak, A.N. and Shapiro, V.A., 2002. The influence of electro-osmotic pressure generating by geomagnetic disturbances on the evolution of seismotectonic process. In: M. Hayakawa and O.A. Molchanov (eds.), "Electromagnetic: Lithosphere-Atmosphere-Ionosphere Coupling", *Terrapub*, Tokyo, p. 203-207.

James, P., 2000. On state of stress in the earth's crust: interferences from reservoir induced seismicity. *New Concepts in Global Tectonics Newsletter*, no. 17, p. 8-10.

James, P., 2014. Artificially induced earthquakes. *New Concepts in Global Tectonics Journal*, v. 2, no. 4, p. 50-61.

Jusoh, M.H. and Yumoto, K., 2011. Possible correlation between solar activity and global seismicity. *Space Environment Research Center of Kyushu Universit*y, ISW/MAGDAS School, Lagos, Nigeria.

Jusoh M. H., Yumoto, K., Abdul Hamid. N. S. and Liu, H., 2012. Electromagnetic coupling on solar-terrestrial system: possible effect on seismic activities. ISAP2012, Nagoya, Japan.

Kotsarenko, A., Perez Enriquez, R., Lopez Cruz-Abeyro, J.A., Koshevaya, S., Grimalsky, V. and Zuniga R.F., 2004. Analysis of the ULF electromagnetic emission related to seismic activity, Teoloyucan geomagnetic station, 1998–2001. *Natural Hazards and Earth System Sciences,* v. 4, p. 679–684.

Li, M., Lu, J., Parrot, M., Tan, H., Chang, Y., Zhang, X. and Wang, Y., 2013. Review of unprecedented ULF electromagnetic anomalous emissions possibly related to the Wenchian Ms = 8.0 earthquake, on 12 May 2008, *NHESS (Natural Hazards and Earth System Sciences),* v. 13, p. 279-286.

Makarova, L.N., and Shirochkov, A.V., 1999. "On the connection between the Earth"s magnetosphere magnetopause position and the earthquakes occurrence", In: Abstracts of XXVI *General Assembly LJRSI*, Toronto, Canada, August 13-21, p. 755.

Mekhtiyev, S.F. and Khalilov, E.N., 1985. About possibility of detection of connection between volcanic eruptions and solar activity. *Volcanology and Seismology*, n. 3, p. 64-67.

Nicholson, C., Roeloffs, E. and Wesson, R.L., 1988. The Northeastern Ohio earthquakes of 31 January 1986: Was it induced? *Bulletin of the Seismological Society of America*, v. 78, no. 1, p. 188–217.

Nikolaev, A., Ruff, L. and Zimakov, L., 1995. Triggering of earthquakes// Earthquake Induced by Underground Nuclear Explosion*, NATO ASI Series 2. Environment,* v. 4, p. 75-84.

Odintsov, S., Boyarchuk, K., Georgieva, K., Kirov, B. and Atanasov, D., 2006. Long-period trends in global seismic and geomagnetic activity and their relation to solar activity. *Physics and Chemistry of the Earth*, v. 31, p. 88–93.

Prikryl, P., Muldrew, D.B. and Sofko, G.J., 2003. High speed solar wind, auroral electrojets and atmospheric gravity waves: a link to the earth's atmosphere, In: Proc. of the *Int. Solar Cycle Studies Symp*. 2003: Solar Variability as an Input to the Earth Environment, June 23–28, 2003, Tatranska Lomnica, Slovakia, ESA-SP.

Simpson, I.F., 1968. Solar activity as a triggering mechanism for earthquakes. *Earth and Planet, Sci. Letter*, v. 3, n. 5, p. 417-425.

Smirnov, V., Chadha, R.K., Ponomarev, A., Srinagesh, D. and Potanina, M., 2014. Triggered and tectonic driven earthquakes in the Koyna–Warna region, western India. *Journal Seismology,* v. 18, p. 587–603.

Sobolev, G.A., Shestopalov, I.P. and Kharin, E.P., 1998. Geophysically significant solar flares and seismic activity of the Earth. *Fiz. Zemli*, no. 7, p. 85-90.

Straser, V., 2011. Radio anomalies and variations in the Interplanetary Magnetic Field (IMF) used as seismic precursors on a global scale. *New Concepts in Global Tectonics Newsletter*, no. 61, p. 52-65.

Straser, V., 2012. Intervals of pulsation of diminishing periods and radio anomalies found before the occurrence of M6+ earthquakes. *New Concepts in Global Tectonics Newsletter*, no. 65, p. 35-46.

Straser, V., Cataldi, G. and Cataldi, D., 2015. Solar wind ionic variation associated with earthquakes greater than magnitude 6.0. *New Concepts in Global Tectonics Journal*, v. 3, no. 2, p. 140-154.

Velinov, P., 1975. "The effect of solar activity on geophysical processes", *Bu/g Geofiz. Spis*., v. 1, p. 51-77.