SOLAR WIND PROTON DENSITY INCREASE AND GEOMAGNETIC BACKGROUND ANOMALIES BEFORE STRONG M6+ EARTHQUAKES

V. Straser*, G. Cataldi

*International Earthquake and Volcano Prediction Center
E-mail: valentino.straser@alice.it

Abstract. This research analyses the relationships between ion density variations in the solar wind, recorded by the ACE satellite, and variations in the geomagnetic and interplanetary magnetic fields, as measured by the GOES 13 and 15 satellites before earthquakes with a magnitude of M6+. From the data presented, from January 1, 2012 to 31 December 2013, correlations can be established between solar activity, seismic events, and the geomagnetic background linked to the plasmasphere.

1. Instruments used

The geomagnetic field is detected by analogue radio receivers – ultra-low-noise high-speed precision operational-amplifiers in the SELF bands (<3 Hz), ELF (3-30 Hz), SLF (30-300 Hz), ULF (300-3000 Hz), VLF (3-30 kHz) and LF (30-300 kHz), using coil antennas and antennas sensitive to magnetic fields. The SELF/ELF radio receiver equipped with a coil antenna vertically aligned parallel to the Z-component of the geomagnetic field is formed by three multilayer coils wound around a ferromagnetic core and connected in series (magnetic induction antenna) for a total of 468.4k windings.

The total theoretical inductance reaches 1.18MH. Digital-to-Analogue Conversion (DAC) of the signals is performed at 24-bit with a Sample Rate of 192kHz and a resolution varying between 0.5 and 3Mhz.

2. Area of Experiment and Preliminary Data Analysis

The data used (from January 1, 2012 to 31 December, 2013) concern the change in solar wind ion density detected by the ACE satellite in orbit near L1 Lagrange, 1.5 million km from Earth; the Solar

Wind Density (ENLIL Heliosphere Ecliptic Plane); variations in the Interplanetary Magnetic Field or IMF (GOES) and the flow of X-rays (GOES). The induction magnetometer of the Radio Emissions Project station is located at Albano Laziale, Rome, Italy, Lat: 41°41'4,27"N, Long: 12 ° 38 '33.60 "E, and reads the intensity and frequency of the Earth's magnetic field every 60 seconds. The data series was labelled with time markers of M6+ seismic events that took place on a global scale (provided in real time by the USGS, INGV and CSEM), which confirmed the existence of perturbations in the interplanetary medium (solar wind) and in the Earth's geomagnetic field in the interval of time preceding the M6+ seismic events [1]. The results of the study showed that the M6+ seismic events that occurred between 2012 and 2013 were all preceded by an increase (of a "gradual" type) in solar wind proton density, plus an increase in the Z component of the earth's magnetic field (Fig 1).

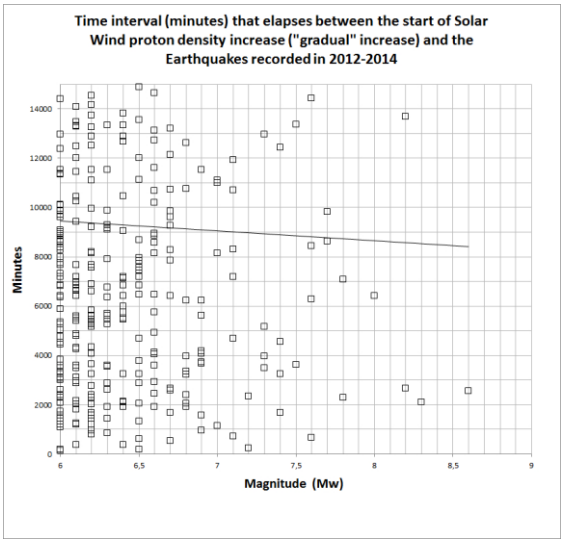

Figure 1. The time interval (in minutes) that elapses between the start of a (gradual) solar wind proton density increase and the earthquakes recorded in 2012-2014.

3. Seismic Geomagnetic Precursors (SGP) and earthquakes

Seismic Geomagnetic Precursors or SGP are variations in the Earth's geomagnetic field, (geomagnetic anomalies), associated with a change in solar activity, which precede strong M6+ earthquakes [2,3]. As shown by the data from monitoring the SELF-ELF band, the spectrographic characteristics of these radio emissions are identifiable as typical of a geomagnetic disturbance that occurs due to an increase in solar activity, and show up as general increases in the Earth's geomagnetic field at a frequency ranging from <3Hz to ~10-15Hz, with an intensity directly proportional to their wavelength. The same anomalies, if observed through a fluxgate magnetometer, reveal intense geomagnetic field variations produced by the increase in solar activity.

By analysing data on global M6+ seismic activity, and data from electromagnetic monitoring of the SELF/ELF band between January 1, 2012 and December 31, 2012, it has emerged that all M6+ earthquakes that took place 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 (Fig. 2) recorded for an electromagnetic anomaly (SGP), it was possible to calculate the time lag between this and the M6+ earthquake. The average time lag was ~598 minutes (~9 hours). The minimum time lag recorded was 1 minute (M6.4 Balleny Islands, October 9, 2012); the maximum time lag recorded was 2,241 minutes (M6.0, Kuril Islands, September 9, 2012). The distribution of the time intervals tends to decrease in relation to the increase in earthquake magnitude.

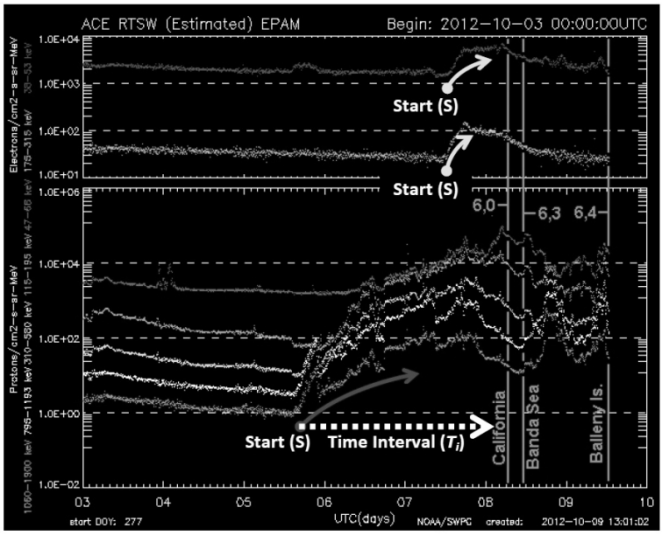

Figure 2. Solar wind ion density related to global M6+ seismic activity. S (the beginning of the increase), Ti (the time between the proton increase and the associated earthquake).

4. Variation in proton density and earthquakes

Analysis of ionic variation in the solar wind (interplanetary medium) has confirmed that all M6+ earthquakes that occurred on a global scale between 2012 and 2013 happened after a "gradual" change in proton density with energy divided into 5 groups: 1060-1900 keV, 795-1193 keV, 310-580 keV, 115-195 keV, 47-68 keV. In some cases, an increase in proton density was overlapped by an increase in electron density with energy divided into 2 groups: 175-315 keV e 38-53 keV.

The increases occurred as the result of a solar flare or the presence of a coronal hole. The ion increase recorded by the ACE Satellite near the L1 Lagrange Point was observed using data provided by the Solar and Heliospheric Observatory (SOHO) and the WSA (Wang-Sheeley - Arge) ENLIL Heliosphere Nowcast (CCMC, University of Colorado).

The data measuring the ion density were converted into "Dyinamic Plots" and published on the website of the National Oceanic and

Atmospheric Administration (NOAA)/SWPC (Space Weather Prediction Center).

The average time lag between the increase in solar activity and the 360 M6+ earthquakes was 9,958.4 minutes (quantifiable as 165.9 hours or 6.9 days). The maximum time lag was recorded before the M7.0 earthquake that struck Indonesia on April 6, 2013. The minimum time lag was recorded before the M6.0 earthquake in the Mariana Islands on November 19, 2013.

5. Implications of the theory and experimental comparisons

The variation in the Earth's geomagnetic activity was primarily modulated by the variation in ion density (protons and electrons) present in the interplanetary medium that interacts with the Earth's magnetosphere, and the amount of X-rays that, starting from the solar corona, reach the earth's ionosphere [4].

All the earthquakes analysed (Fig. 3) were preceded, albeit with variable timing, by an increase in proton density. While, in general, it was noted that an ion increase can even precede more than one M6+ seismic event, for example, in the case of the recent earthquakes that occurred in July 2014, which struck 7 days after a major increase in solar activity.

The perturbation arriving from the Sun was intercepted by the ACE satellite, and a few minutes later also by GOES 13 and 15. After the latter, from measurements of the variation in the geomagnetic field, several hours may pass. The temporary interruption of the flow may be interpreted as the time necessary to "inject" the high-energy particles into the plasma sphere.

The time interval between the values given by GOES 13 and 15 and the associated earthquake, is instead recurring, and varies according to multiples of 8 minutes, a time interval that agrees with the study by Dr. David Sibek; the two fields merge or "reconnect" briefly, forming a portal through which the particles flow [5,6].

Overall, 94% of the M6+ earthquakes studied occurred after the onset of a radio anomalies, an increase in the geomagnetic background, and subsequent normalisation; the remaining 6% during the increase itself. In particular: 29% of the M6+ earthquakes occurred within 1

hour of the normalization of the geomagnetic background; 16% within 61-120 minutes, 12% within 121-240, 28% within 241-480 further minutes, 15% of the earthquakes after more than 8 hours.

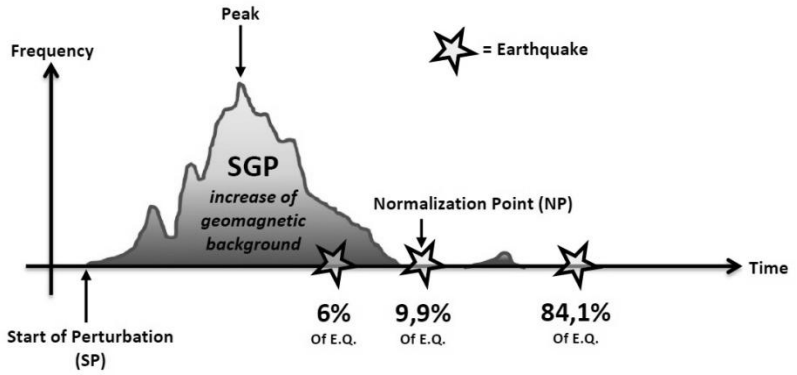

Figure 3. Spectrographic characteristics of the Seismic Geomagnetic Precursors (SGPs) and time intervals associated with the M6+ seism that occurred in 2012.

6. Results of the correlational study

Analysis of the data on solar activity, geomagnetic activity and global M6+ seismic activity has confirmed that between January 1, 2012 and 31 December, 2013 global seismic activity has always been preceded, in comparable intervals, by a rise in proton density of the interplanetary medium recorded by the ACE (Advanced Composition Explorer) Satellite, in orbit around the L1 Lagrange point, at 1.5 million km from Earth, from an increase in the geomagnetic background and geomagnetic anomalies, detected 24/7 by the Radio Emissions Project monitoring station (Albano Laziale, Rome, Italy).

For application, the method lends itself as a candidate to analyse M6+ seismic precursors on a global scale, and to check a link and

synchronicity of an electromagnetic type between the Sun and the Earth.

References

1. G.Cataldi, D.Cataldi, V.Straser, Earth's magnetic field anomalies that precede the M6+ global seismic activity. Geophysical Research Abstract, Vol 16, EGU2014-1068, 2014, EGU General Assembly 2014.
2. G. Cataldi, D. Cataldi, V. Straser, "Variations Of Terrestrial Geomagnetic Activity Correlated To M6+ Global Seismic Activity" Geophysical Research Abstracts, Vol. 15, EGU (European Geosciences Union) General Assembly 2013.
3. J.Y.Liu, Y.I.Chen, S.A.Pulinets, Y.B.Tsai, Y.J.Chuo. Seismo-ionospheric signatures prior to M≥6.0 Taiwan earthquakes. Geophysical Research Letters, 2000, v. 27, Issue 19, p. 3113-3116.
4. Khazaradze, N.G., Metskhvarishvili, R. Ya., Elizbarashvili, M.A., Mininoshvili, Z.N., Metskhvarishvili, I.R., Nekrasova, V., Metskhvarishvili, M.R., and Khorbalazde, L.R.,. Anomalous solar-diurnal variations in cosmic rays related to crossing of the IMF sector boundaries by the Earth and the problem of earthquake. Geomagnetism and Aeronomy, 2007, v. 47, no.3, p. 395-398.
5. V.Straser, Can IMF And The Electromagnetic Coupling Between The Sun And The Earth Cause Potentially Destructive Earthquakes?, New Concepts in Global Tectonics Newsletter, 2012, no. 65, p. 27-34.
6. Phillips, T., 2008. Magnetic Portals Connect Earth to the Sun. http://science.nasa.gov/headlines/y2008/30oct_ftes.htm