Solar and electromagnetic signal before Mexican Earthquake M8.1, September 2017

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Abstract: In this study we analyze electromagnetic and solar phenomena that preceded the strong Mexican earthquake, magnitude M8.1, which occurred on September 7, 2017 with epicenter in the Tehuantepec Gulf. The data analysis is aimed at comparing it with other geomagnetic and solar signals that preceded strong earthquake on global-scale with the aim of adding new knowledge to seismic precursor candidates or seeking new search bases on crustal diagnosis. The rock deformation under tectonic stress, in the seismic area, that precedes a seismic event is the most appropriate phase of investigation for the analysis of measurable effects that are produced on the Earth's surface before an earthquake, including electromagnetic manifestations. The earthquake of Mexico is the strongest in the recent history of geophysics, and that occurred after significant variations in solar activity, measured by satellites and monitoring stations placed in various countries. The data are consistent with other M6 + earthquakes, studied starting in 2012 and today that exceed 900 seismic events. The main shock was preceded by radio-anomaly detection at frequencies below 3Hz, which according to the authors, always appear before potentially destructive earthquakes.

Keywords - *Earthquakes precursors, Mexican earthquake M8.1, geomagnetic variations, radio anomalies, solar activity.*

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Introduction

For some years, a possible link between solar activity, magnetic anomalies and earthquakes is gaining increasing interest in the fields of research in Physics, Geotectonics and Seismology. Specifically, the crustal diagnosis made with the detection of radio anomalies in the frequency band from 0.01 to 3Hz, is an emerging aspect for the study of tectonic stress and earthquakes. Equally, studies of the same importance that consider magnetic variations, detected by observers are located on different continents, that precede earthquakes of magnitude equal to or greater than M6 of the Richter scale (Cataldi et al., 2013; Straser et al., 2016). These strong energies can be associated with the breaking of rocks caused by tectonic stress and not by elastic returns. In the preparatory stages of the strong earthquakes, the rocks undergo major modifications (Di Toro et al., 2010), with the possibility of emitting electromagnetic signals. The frequency band for detection of such anomalies is the ELF or even SELF (Straser, 2011, Cataldi et al., 2017), and it is not being produced, among other things, by anthropic activities. Electromagnetic signals are associated with external influences of interplanetary origin and, in particular, the solar activity in the phase of massive quantitative activity of external energy (Straser and Cataldi, 2014). Energy particles transported by the solar wind, in interplanetary space, also strike the highest layers of the Earth's atmosphere (Rajesh et al., 2014). This huge flow of energy comes on the planet, producing strong atmospheric anomalies. Under the pressure of the solar wind load energy, the Earth's magnetic field can be deformed (Simpson, 1968; Choi and Maslov, 2010; Shestopalov and Kharin, 2014). The contraction and expansion of the Earth's magnetic field causes interference on the waves of radio signals. The occurrence of powerful solar emissions can also cause a strong instability of the magnetic field itself, which in turn would exert deep repercussions, acting on existing balancing forces within the Earth's crust, and with these, telluric activity (Sytinskiy, 1963; Odintsov et al., 2006; Gousheva et al., 2003). Research fields are still in a pioneering phase and not all scientists agree to consider the validity of these phenomena (Love et al., 2013). This study therefore aims to add a new element to the understanding of this complex mosaic. The recent Mexican earthquake that causing deaths, huge damage to structures and the economy, it was the occasion to study the electromagnetic signals that preceded the strong earthquake, similar to other earthquakes with magnitudes higher than M8+ (Straser et al., 2015; Han et al., 2004).

Mexico M8.1 Earthquake

The main shock was recorded on Thursday 7 September 2017 at 23:49:18 local time (CDC) with a magnitude of 8.4Mw, or M8.1 calculated by USGS. The epicenter was located at a depth of about 70 kilometers in the Gulf of Tehuantepec, 137 kilometers southeast of Pijijiapan, off the coasts of the Mexican state of Chiapas (**Fig. 1**).

Fig. 1. Index map.

Characteristic of seismic geomagnetic Precursor or SGP

Seismic Geomagnetic Precursors (SGPs) are variations in the Earth's geomagnetic field (geomagnetic anomalies) associated with a variation in solar activity that preceded strong earthquakes (earthquakes having a magnitude of at least Mw6 or M6+). According to the data derived from the SELF-ELF band monitoring, the spectrographic characteristics of these radio emissions are identifiable as those typical of a geomagnetic perturbation that occurs as a result of an increase in solar activity and are highlighted as generic increases in the geomagnetic field a frequency between <3 Hz and ~10-15 Hz, with intensity directly proportional to their wavelength. The same anomalies, if observed through a fluxgate magnetometer that produces magnetograms, are highlighted as intense variations of the geomagnetic field produced as a result of an increase in solar activity. The first instrumental observation of a SGP was made by the authors in 2010, but only in recent years it was possible to correlate these emissions with solar activity. Analyzing data on global M6+ seismic activity and on SELF-ELF band monitoring between January 1, 2012 and December 31, 2012 showed that all M6+ earthquakes occurring on a global scale were preceded by an increase in the natural electromagnetic background between <3 Hz and ~10-15 Hz. Referring to the maximum recorded intensity of the electromagnetic disturbance (SGP), it was possible to calculate the time difference between this and the M6+ earthquake: the average time interval recorded was ~598 minutes (~9 hours). The minimum time interval recorded was 1 minute (M6.4 Balleny Islands earthquake, October 9, 2012); the maximum recorded time interval was 2241 minutes (M6.0 Kuril Islands earthquake, September 9, 2012).

Methods and data

To realize this study, the authors analyzed the space weather conditions (near Earth) and the characteristics of the geomagnetic field in the days that preceded the strong earthquake. In particular, the data taken into consideration were: data on the solar activity concern variation in the ionic density of the solar wind detected by the ACE (Advanced Composition Explorer) satellite orbiting the L1 point (Lagrange point) at 1.5 million kilometers from Earth; Solar Wind Density (ENLIL Heliosphere Ecliptic Plane), variations in interplanetary magnetic field or IMF (GOES); X-ray flux (GOES), temporal monitoring of CMEs events or Solar Coronal Mass Ejections (ISWA); monitoring of the coronal holes position on the Sun's surface (NSO/SOLIS-VSM Coronal Hole); Solar Wind Velocity (ENLIL Heliosphere Ecliptic Plane); Electron flux (NOAA/SWPC); Magnetopause Standoff Distance (CCMC/RT). The data on geomagnetic activity used for the study are represented by Kp-Index and were provided by Space Weather Prediction Center (SWPC). Earth's geomagnetic field variation recorded by Tromso Geomagnetic Observatory, and Dikson Geomagnetic Observatory. In Italy, the data is collected at the LTPA Observer Project monitoring station, Radio Emissions Project, Albano Lazio (Rome). The geomagnetic field monitoring methodology adopted by the authors is based on the use of analogue radio receivers equipped with ultra-low-noise high-speed precision operational-amplifiers (Cataldi and Cataldi, 2013) capable of working efficiently and with low noise electronic, in the bands: SELF (<3 Hz), ELF (3-30 Hz), SLF (30-300 Hz), ULF (300-3000 Hz), VLF (3-30 kHz) and LF (30-300 kHz) through the use of wire-loop antennae and antennas sensitive to the magnetic fields (coils) aligned according to the vector components of the geomagnetic field.

Results

The results of the study have confirmed the hypothesis of the authors: that the Mexican M8.1 earthquake was preceded by an increase of the interplanetary medium ion density (near Earth), also confirming what the authors ascertained from the 2012 data. Specifically, the M8.1 earthquake occurred after an increase of the solar wind proton density started on September 5, 2017 at 04:30 UTC.

1. Solar wind proton density

The energy fraction of the protons that was taken as reference was 761-1220 keV, 1060-1900 keV and 310-580 keV. The graph (**Fig. 2**) shows the variation of the solar wind proton density that was recorded between August 30, 2017 and September 8, 2017 by the Advanced Composition Explorer (ACE) Satellite, in orbit at L1 Lagrange point, at 1.5 million km from Earth, in the direction of the Sun. The variation of the solar wind proton density was superimposed on the temporal data of the M8.1 seismic event occurring in Mexico on September 8, 2017 at 04:49:21 UTC (vertical black arrows). The beginning of the protonic rise (indicated by the big purple arrow) occurred at 04:30 UTC on September 5, 2017; between 6 and 7 September 2017 the proton density reaches its maximum intensity. 72 hours and 19 minutes after the start of the protonic rise was recorded the M8.1 Mexican earthquake. The protonic increase also generated a geomagnetic perturbation that reached grade 4 (G4) on the NOAA (National Oceanic and Atmospheric Administration) Geomagnetic Activity Scale (corresponding to a Kp-Index of 8; the perturbation was highlighted in yellow with a dotted red line). This geomagnetic perturbation preceded the M8.1 Mexican earthquake of 7 hour and 49 minute. During the seismic event, the geomagnetic perturbation was reduced to grade 1 (G1). The beginning of the protonic rise (purple large arrow) has been defined by the authors as "Interplanetary Geomagnetic Precursor" because it preceded the strong earthquake: this is a phenomenon observed by the authors since 2012.

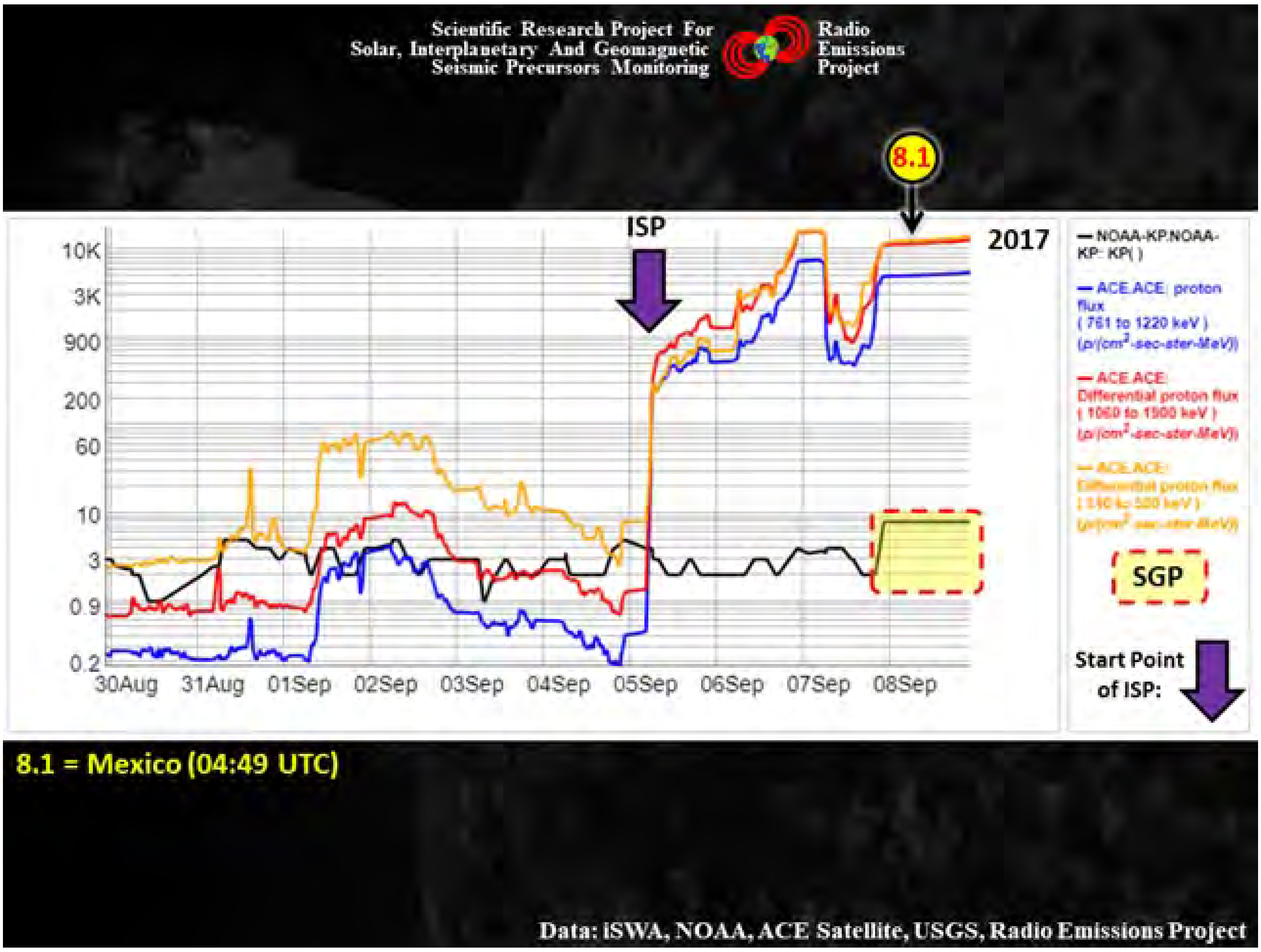

Fig. 2 Solar wind proton density variation that preceded the M8.1 Mexican Earthquake

2. G4-G1 Geomagnetic storms

The solar wind proton density increase that reached the Earth on 5 September 2017 at 04:30 UTC and to which the effects of a two class X flare have been added (**Fig. 3**). The first solar flare (GOES Class = X9.3) started at 11:53 UTC, peaked at 12:02 UTC and ended at 12:10 UTC of September 6, 2017; the second solar flare (GOES Class = X1.3) started at 14:20 UTC, peaked at 14:36 UTC and ended at 14:55 UTC of September 7, 2017. In addition to the two class X flares, other lower class flares (M) were also recorded between 6 and 8 September 2017. All of these solar flares contributed to generating an intense geomagnetic perturbation that began before the M8.1 Mexican earthquake and protracted for several hours later. Analyzing geomagnetic activity, it is clear that the M8.1 earthquake occurred in Mexico on September 8, 2017 at 04:49:21 UTC were preceded by wide geomagnetic storms that reached G4 and G1 grade: the super geomagnetic storm (G4 grade) started on September 7, 2017 at 21:00 UTC and ended at 03:00 UTC on 8 September 2017. Between 03:00 UTC and 06:00 UTC, the super storm has decreased intensely reaching G1 grade: at this time the strong Mexican earthquake has been recorded.

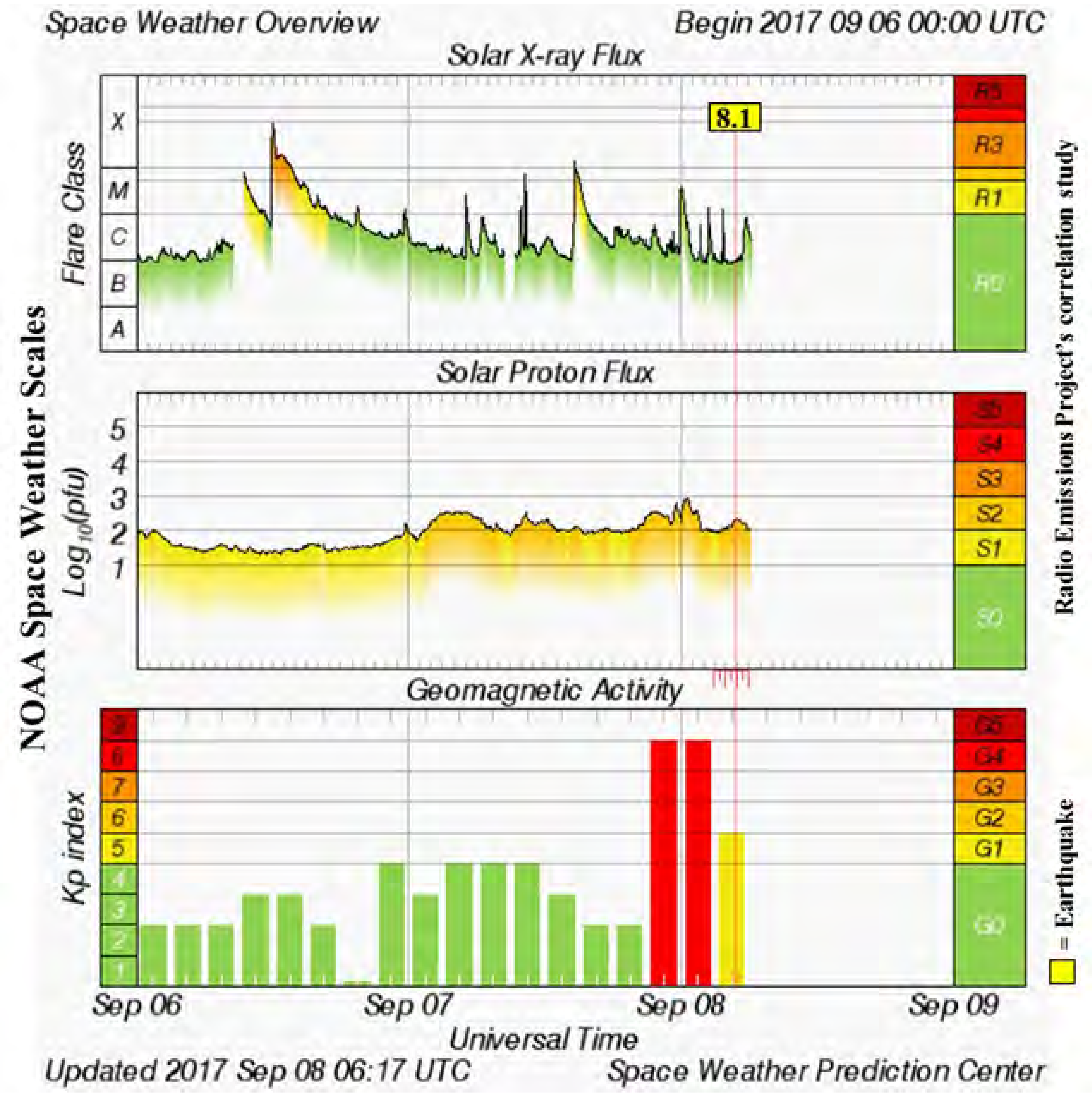

Fig. 3. G4-G1 Geomagnetic Storms: The image shows the modulation of the NOAA (National Oceanic and Atmospheric Administration) Space Weather Scales recorded between 6 and 8 September 2017.

3. Earth's geomagnetic field variation

Magnetogram containing the variation of the Earth's geomagnetic field, relative to Z (green line), H (blue line) and D (red line) component, registered by the Dikson Geomagnetic Observatory (DIK), Russia, between 7 and 8 September 2017 (**Fig. 4**). The Z component is a vertical component, assumed positive when it's directed towards the inside of the Earth. The H component is the horizontal component, namely the component aligned in the direction of the magnetic North. The D component is magnetic declination angle between the direction of H and the geographic meridian passing through the point in question (Dikson Geomagnetic Observatory), taken as positive when H is directed to the East of the geographic Nord. The vertical black lines represent the temporal markers of M8.1 earthquakes occurred in Mexico on September 8, 2017; while the numbers represent the magnitude (Mw) of earthquakes. Analyzing the chart, it can be seen that the strong Mexican earthquake was preceded by intense geomagnetic perturbation which started at 20:30 UTC on September 7, 2017 and which ended a few minutes before the strong seismic event. In particular, the Dikson Geomagnetic Observatory detected an oscillation of the magnetic North pole that exceeded +16 degrees. In addition, the H geomagnetic component has suffered a reduction of

approximately 1900 nT in a few hours.
By analyzing the temporal modulation of the solar wind speed is evident that the strong Mexican earthquake occurred during a strong increase of the solar wind speed. The increase exceeded 1100km/s few minutes before the seismic event (**Fig. 5**)

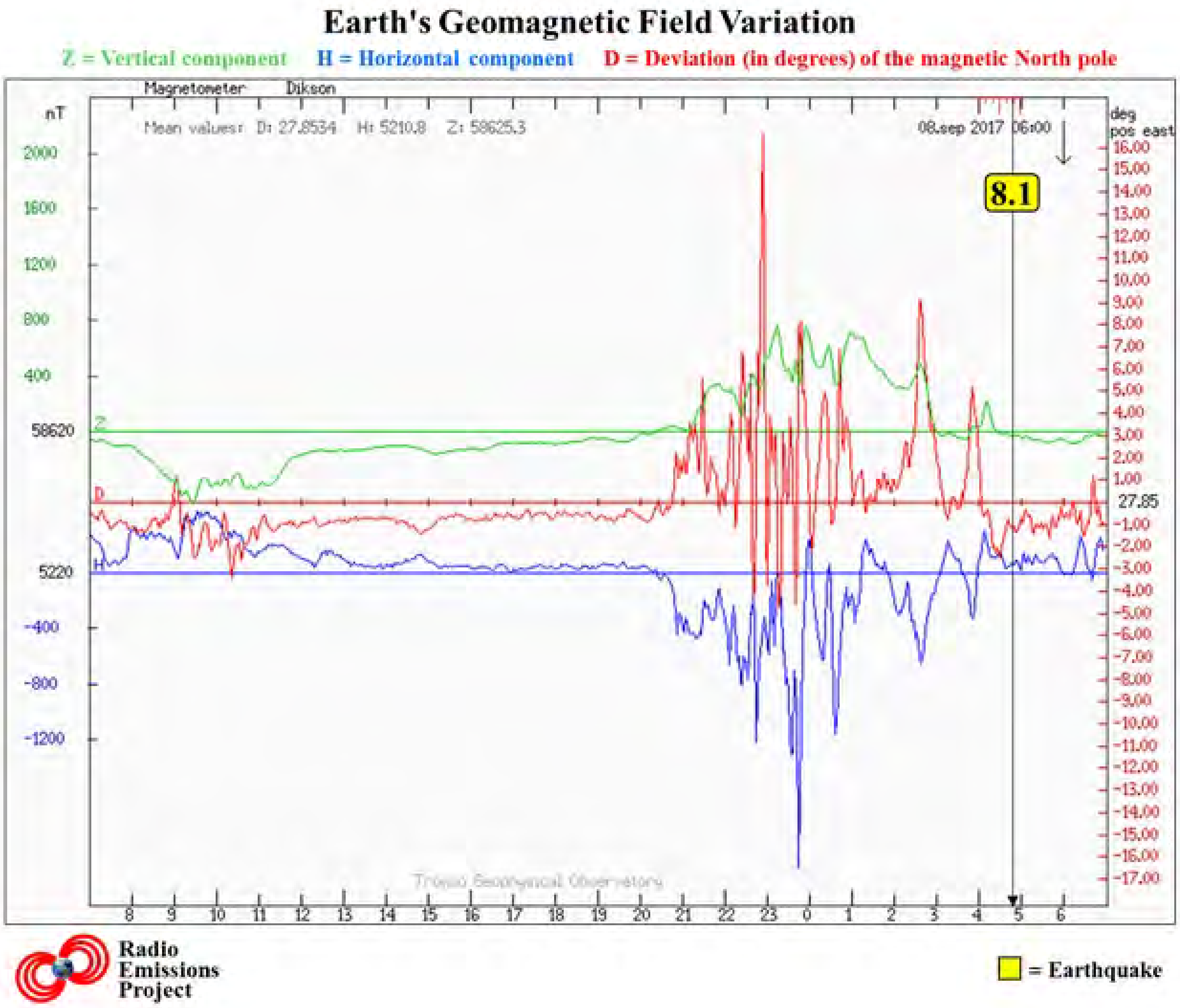

Figure 4. Earth's geomagnetic field variation recorded by Dikson Geomagnetic Observatory.

Fig. 5. Solar Wind Velocity: The picture shows the graph of the solar wind speed recorded between 5 and 8 September 2017 near the Earth. Credits: ISWA Timeline Interactive.

4. Hemispheric Power

The vertical red arrow represents the temporal marker of the M8.1 Mexican earthquake recorded on September 8, 2017 by Polar-orbiting Operational Environmental Satellite (POES). According to the data currently proposed, the strong Mexican earthquakes were preceded by an increase in solar activity and in Earth's geomagnetic activity (**Fig. 6**). Authors have observed this kind of correlation since 2012.

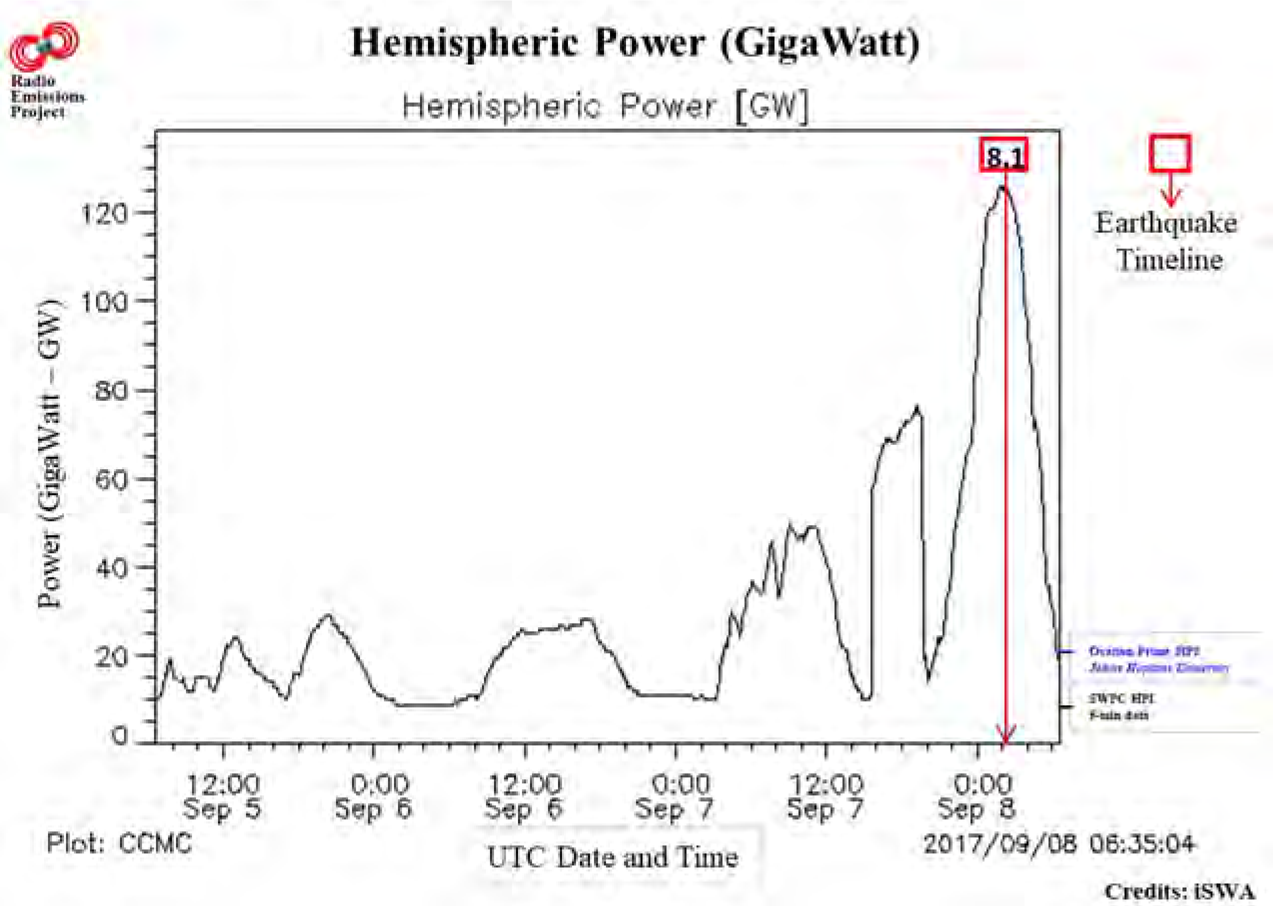

Fig. 6. Hemispheric Power: The graph shows the variation of the magnetopause standoff distance recorded between 6 and 8 September 2017

5. Magnetopause standoff distance

Analyzing the graph (**Fig. 7**), it is evident that the strong Mexican earthquake was preceded by a drastic reduction of the magnetopause standoff distance[2]. The vertical red arrow represents the temporal marker of the M8.1 Mexican earthquake recorded on September 8, 2017. The standoff distance has been reduced so drastically as to fall below the geosynchronous orbit (between 7 and 8 September 2017). This data confirms that the Earth has been reached by an important coronary mass ejection (CME).

[2] The magnetopause standoff distance is the distance (expressed in earth rays) that separates Earth magnetopause from the center of the Earth. This measure is a direct index of solar activity as it varies according to the dynamic pressure of the solar wind: major the density and speed of the solar wind, lower will be the magnetopause standoff distance on the side facing the sun. Because the magnetopause undergoes oscillations more or less intense in relation to the characteristics of the solar wind.

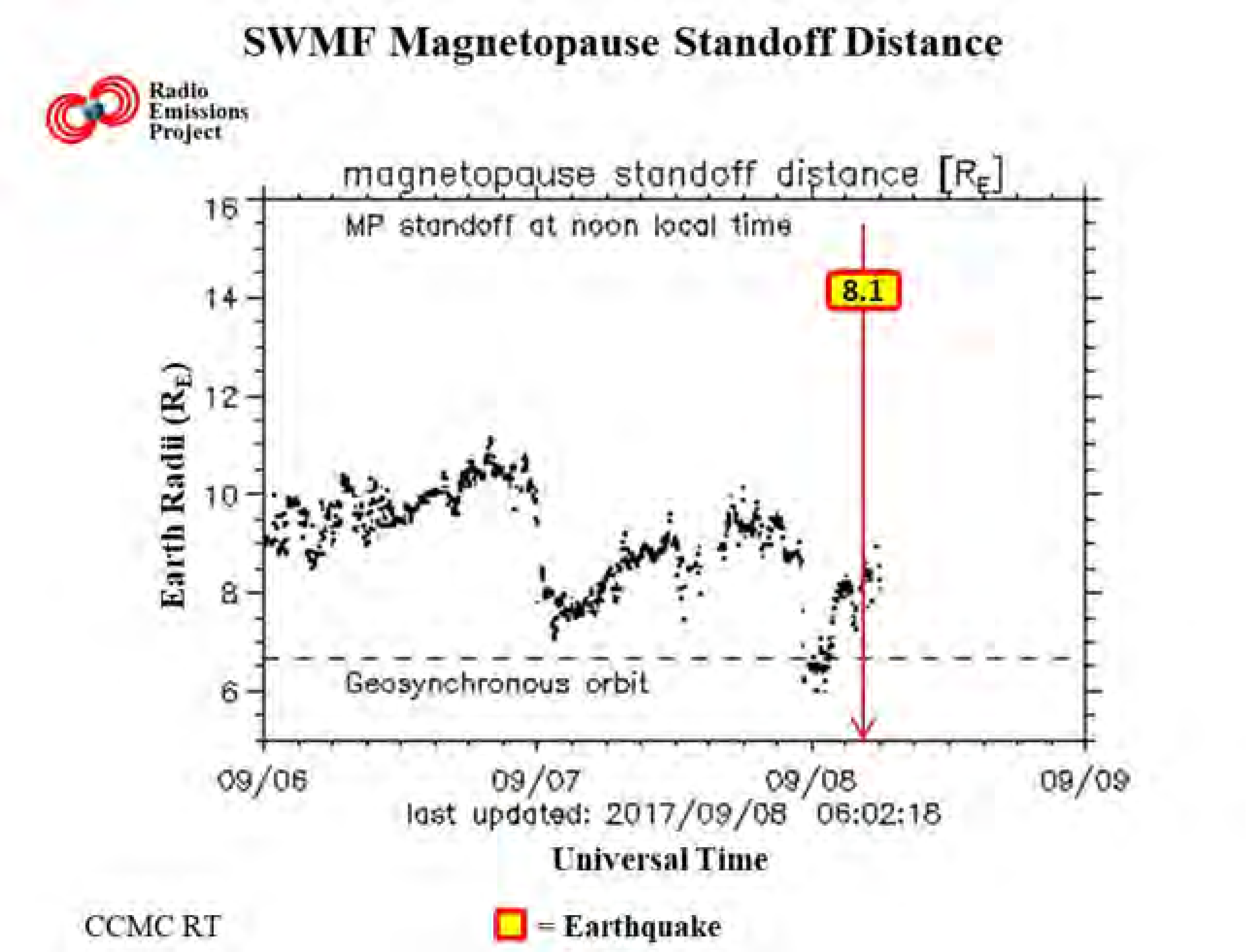

Fig. 7. Magnetopause Standoff Distance: The graph above shows the variation of the magnetopause standoff distance recorded between 6 and 8 September 2017.

6. Solar wind temperature

The analysis of the variation curve (**Fig. 8**) confirms that the strong earthquake was preceded by an intense increase in the ionic temperature of the interplanetary medium, which began between 7 and 8 September 2017. The vertical red arrow represents the temporal marker of the M8.1 Mexican earthquake recorded on September 8, 2017. The increase peak was recorded on 8 September 2017 at 01:30 UTC and reached 2.2 million of °K. Authors have observed this kind of correlation since 2012.

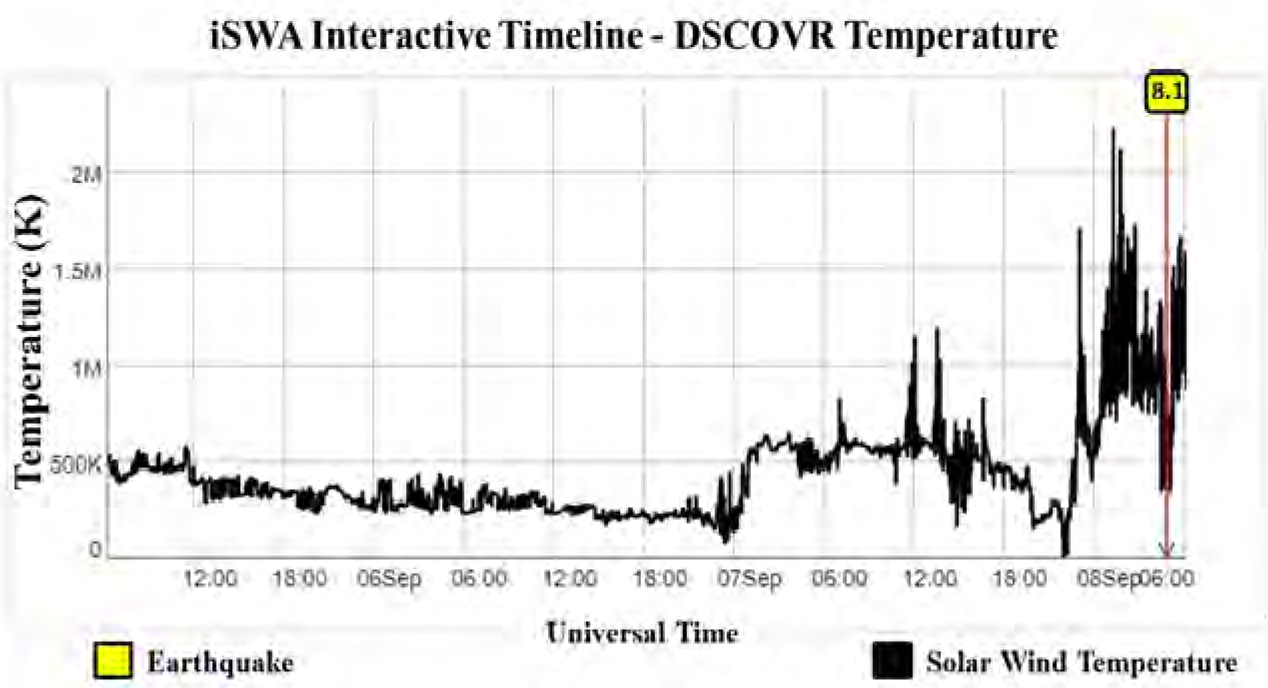

Fig. 8. Solar Wind Temperature: The graph above shows the variation of solar wind ions temperature recorded by Deep Space Climate Observatory (DSCOVR) Satellite, in orbit at L1 Lagrange point, at 1.5 million km from Earth, in the direction of the Sun.

7. Radio anomalies – super extremely low frequency (SELF)

The spectrogram (Fig. 9), recorded by environment monitoring station of Radio Emissions Project, was set to analyze a 1Hz (0-1Hz) bandwidth within the Super Extremely Low Frequency (SELF) band to search for pre-seismic electromagnetic anomalies (Seismic Electromagnetic Precursors or Seismic Geomagnetic Precursors). This monitoring system is active 24H7 and represents the only monitoring station dedicated to SELF electromagnetic and geomagnetic seismic precursors in European territory. Analyzing the spectrogram the authors found that the M8.1 Mexican earthquake occurred on September 8, 2017 at 04:49:21 UTC was preceded by a slight increase in the electromagnetic background (the temporal marker of the Mexican earthquake is indicated by the vertical white arrow, Fig. 9). The increase started at 04:18 UTC of September 8, 2017 and remained visible until 05:02 UTC of September 8, 2017. The anomaly was highlighted with the label "Electromagnetic Anomaly", with horizontal white arrows and two vertical white lines. Also, between 0 and 0.05 Hz, a series of impulse emissions (highlighted by the dotted red line) have been found that coincided with the duration of the anomaly. The duration of the anomaly was a total of 47 minutes and preceded the strong Mexican quake of about 27 minutes. This record demonstrates for the umpteenth time that can be recorded “pre-seismic SELF electromagnetic emissions” correlated to seismic events distant thousands of kilometers from the monitoring station. Authors have first observed this type of radio signal since 2008.

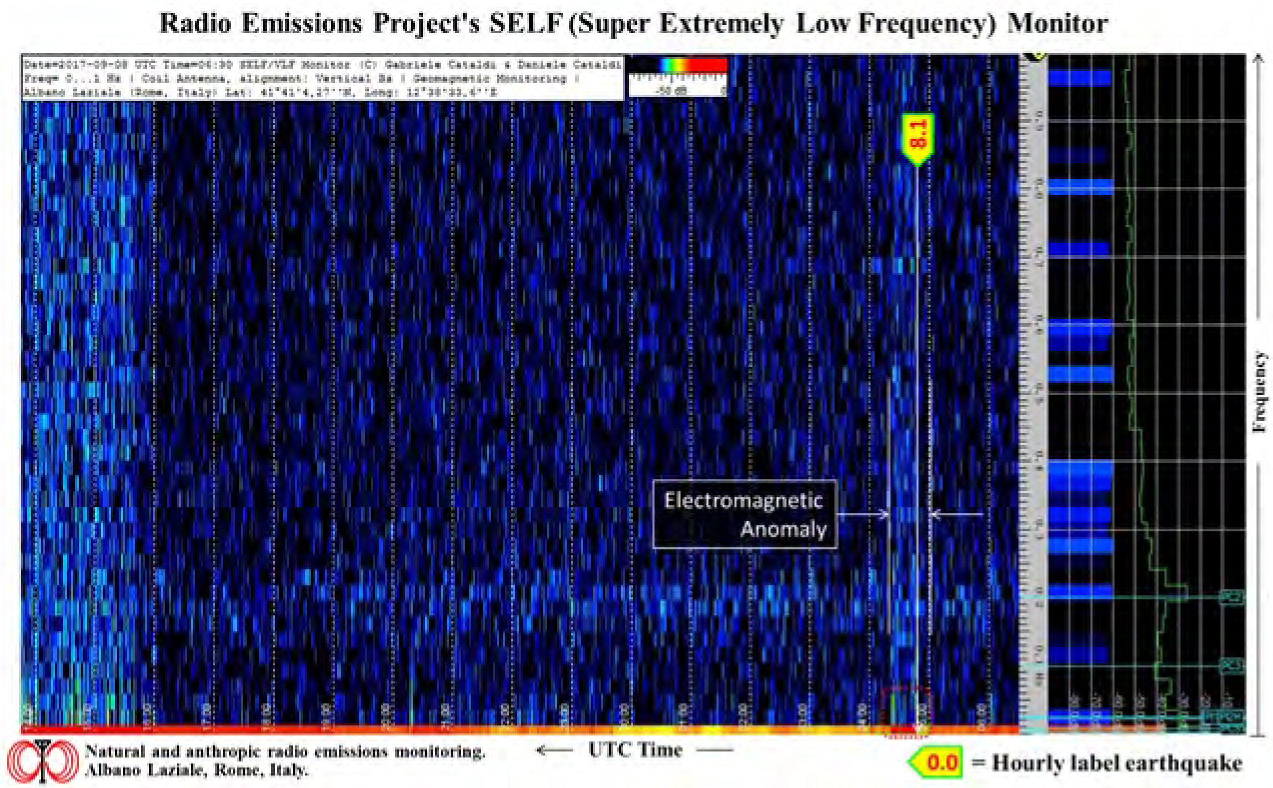

Fig. 9. Radio-anomaly observed in Super Extremely Low Frequency (SELF). The top image represents the dynamic spectrogram of Earth's electromagnetic field (SELF band, 0<f<3 Hz) recorded between 14:00 UTC of September 7, 2017 and 06:30 UTC of September 8, 2017 from the electromagnetic environment monitoring station of Radio Emissions Project, located at Albano Laziale (RM), Italy (Lat: 41°42’7,52”N; Long: 12°49’17,34”E).

Conclusions

We conclude that the solar wind, interplanetary and geomagnetic data, presented in this study confirm the occurrence of these anomalies before an earthquake greater than magnitude M6+, studied by the authors starting in 2012. These values occur both for earthquakes in recurrent seismic areas and episodes. In this sense, Mexico's earthquake is no exception. The recognition of these physical phenomena before the earthquake, being measurable, is a precursor candidate for attempting a short-term prediction. At the present state of knowledge, the detection and measurement of these anomalies are a starting point for the study of precursors, as confirmed in this study. An interdisciplinary study may add new pieces to the understanding of geophysical phenomena associated activity and solar physics. The data found in this research regarding radio abnormalities confirm the over 900 cases analyzed starting in 2012. The abnormal variations of the physical-mechanical characteristics of rocks under tectonic stress, the medium and the geophysical phenomena underlying the fracturing process, are believed to generate electromagnetic signals, detectable by monitoring stations such as that of Rome. The low frequency range considered the most favorable for the transmission of electromagnetic waves that precede an earthquake is less than <3Hz, named by authors as SELF (Super Extremely Low Frequency), confirmed also in the case of the Mexican earthquake. Subsequent studies in the field of solar activity and the production of EM waves from rocks under tectonic stress will add new knowledge to the understanding of the physical mechanism that generates earthquakes.

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