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Research Article

The Space Weather Related to the M7+ Seismic Activity Recorded on a Global Scale between 28 January and 25 March 2020

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Abstract

This research aims to discuss the variation of solar activity and in particular the proton density connected to seismic events of magnitude greater than 7. Between January 28, 2020 and March 25, 2020, our planet was shaken by three M7+ earthquakes (January 28, 2020 in Jamaica with magnitude of M7.7; February 13, 2020 in Russia with magnitude of M7.0 and, again in Russia, on March 25, 2020 with magnitude of M7.5) and provided the opportunity to carry out the research. The changes in the ionic density of the solar wind that preceded the global seismic sequence occurred after major increases in the proton density of the solar wind. In this regard, the authors analyzed space weather to verify the existence of a correspondence between solar activity and the three M7+ seismic events. The data showed a close relationship between the two variables, in a temporal sense and from a qualitative point of view. The time intervals between the proton density increase and the main tremors were 28 hours, 12 hours, and 112 hours, respectively.

Keywords: Earthquake Prediction; Proton Density; Electromagnetic Seismic Precursors; Global Seismicity; M7+

Abbreviations

ISWA: iNtegrated Space Weather Analysis System; USGS: United States Geological Survey; NOAA: National Oceanic and Atmospheric Administration; ACE: Advanced Composition Explorer Satellite

Introduction

Three seismic events of strong intensity were recorded on Earth between January 28, 2020 and March 25, 2020 (Figure 1):

- M7.7 – Jamaica earthquake (depth 14.9 km); recorded on January 28, 2020 at 19:10 UTC;
- M7.0 – Russia earthquake (depth 143 km); recorded on February 13, 2020 at 10:33 UTC;
- M7.5 – Russia earthquake (depth 57.8 km); recorded on March 25, 2020 at 02:49 UTC.

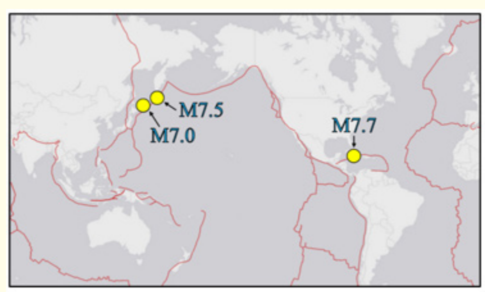

Figure 1: Epicenters of the three potentially destructive seismic events analyzed in this work. The map above shows the seismic epicenters of the following earthquakes: M7.7 - Jamaica earthquake; recorded on January 28, 2020 at 19:10 UTC; M7.0 - Russia earthquake; recorded on February 13, 2020 at 10:33 UTC; M7.5 - Russia Earthquake; recorded on March 25, 2020 at 02:49 UTC. Credits: USGS.

Earthquakes of this magnitude have been correlated by the authors to variations in the solar ion flux [5,7-16,19,24-29] allowing to understand that all M6+ earthquakes that occurs on a global scale is always preceded by an increase in the proton density of the solar wind. What has just been stated represents a very important scientific achievement that the authors made in 2012 and which was presented to the international scientific community in 2013 [5]. From 2013 to today, the authors have repeatedly confirmed this type of correlation by proposing to use it as a useful tool to understand when, on a global scale, a resumption of seismic activity M6+ can be expected. The study presented in this work once again confirms the close correlation identified by the authors between solar activity and potentially destructive seismic activity that is recorded on a global scale and the useful impact this has on the predictive level.

Methods

To verify the existence of a close correlation between solar activity and the three M7+ seismic events discussed in this work, the authors analyzed the ionic variation of the "near Earth" solar wind, and in particular the "Proton Density (cm^{-3})", in the days and weeks that preceded the three seismic events. The data on the solar ion flux were provided by NOAA (National Oceanic and Atmospheric Administration) through the Deep Space Climate Observatory (DSCOVR) Satellite (Figure 2).

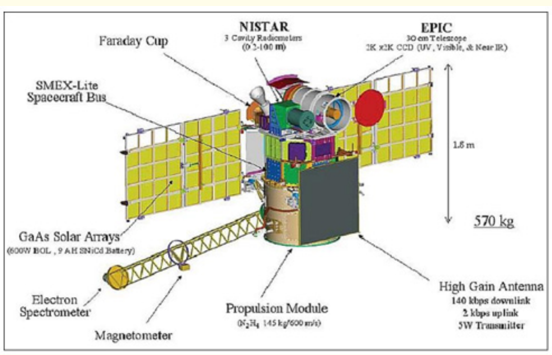

Figure 2: Deep Space Climate Observatory (DSCOVR) Satellite. The image above shows the construction scheme of the Deep Space Climate Observatory (DSCOVR) Satellite. This satellite was launched by SpaceX on February 11, 2015 from Cape Canaveral using a Falcon 9 as a carrier rocket, and is currently located in Lagrangian orbit L1. Credits: https://earth.esa.int/web/eoportal/satellite-missions/d/dscovr.

Results

On January 17, 2020 at 14:50 UTC the Deep Space Climate Observatory (DSCOVR) Satellite begins to record an increase in the proton density of the solar wind that between 18:00 UTC on January 28, 2020 and 10:00 UTC on January 29, 2020 reaches the maximum values (Figure 3). During this phase, two potentially destructive seismic events were recorded on Earth:

- M7.7 – Jamaica earthquake; recorded on January 28, 2020 at 19:10 UTC;
- M6.1 – Cayman Islands earthquake; recorded on January 28, 2020 at 21:55 UTC.

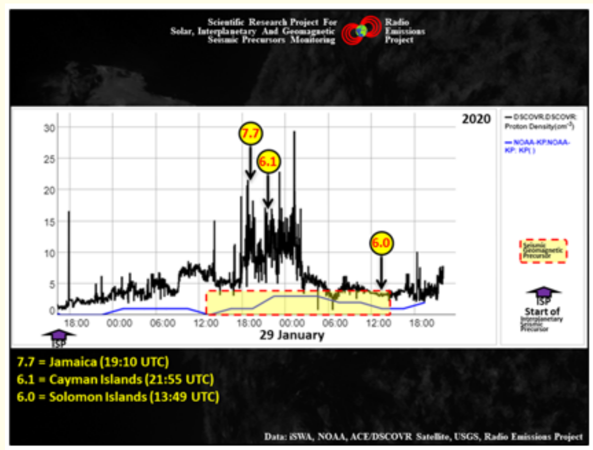

Figure 3: Variations in the ion density of the solar wind that preceded the M6+ global seismic sequence of 28-29 January 2020. In the graph above was highlighted the close correlation found by the authors between solar activity (solar wind) and M6+ global seismic activity which occurred between 28 and 29 January 2020. The vertical black arrows represent the time markers of the M6+ seismic events; the blue curve represents the variation of the Kp index; The black curve represents the variation of the proton density of the solar wind (p/cm^3) recorded through the Deep Space Climate Observatory (DSCOVR) Satellite, positioned in Lagrangian L1 orbit; the yellow area delimited by the dashed red line highlights the temporal position of the Seismic Geomagnetic Precursor (SGP) related to the M6+ global seismic sequence which occurred between 28 and 29 January 2020; the vertical purple arrow, identified with the acronym "ISP", represents the beginning of the Interplanetary Seismic Precursor (ISP) related to the M6+ seismic events. Credits: USGS, NOAA, iSWA, ACE/DSCOVR Satellite, Radio Emissions Project.

About 12 hours after the two seismic events, a third potentially destructive seismic event was recorded:

- M6.0 – Solomon Islands earthquake; recorded on January 29, 2020 at 13:49 UTC.

On February 12, 2020 at 22:00 UTC the Deep Space Climate Observatory (DSCOVR) Satellite begins to record a slight increase in the proton density of the solar wind which will end about 24 hours later (Figure 4). About 12 hours after the start of this proton increase, a potentially destructive seismic event was recorded:

- M7.0 – Russia earthquake; recorded on February 13, 2020 at 10:33 UTC.

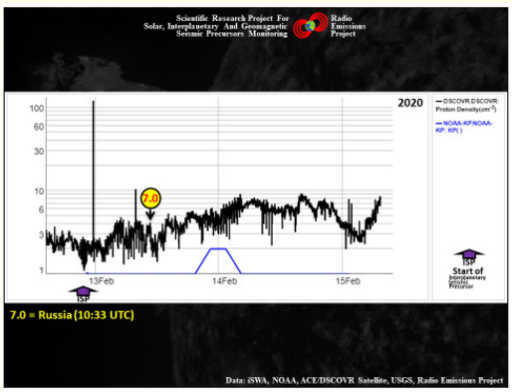

Figure 4: Variations in the ion density of the solar wind that preceded the M7.0 earthquake recorded in Russia on February 13, 2020. In the graph above was highlighted the close correlation found by the authors between solar activity (solar wind) and M6+ global seismic activity occurred February 13, 2020. The vertical black arrows represent the time markers of the M6+ seismic events; the blue curve represents the variation of the Kp index; The black curve represents the variation of the proton density of the solar wind (p/cm^3) recorded through the Deep Space Climate Observatory (DSCOVR) Satellite, positioned in Lagrangian L1 orbit; the yellow area delimited by the dashed red line highlights the temporal position of the Seismic Geomagnetic Precursor (SGP) related to M6+ seismic event recorded on February 13, 2020 ; the vertical purple arrow, identified with the acronym "ISP", represents the beginning of the Interplanetary Seismic Precursor (ISP) related to the M6+ seismic event. Credits: USGS, NOAA, iSWA, ACE/DSCOVR Satellite, Radio Emissions Project.

On March 20, 2020 at 10:33 UTC the Deep Space Climate Observatory (DSCOVR) Satellite began detecting a proton increase in the solar wind that lasted for more than 120 hours. Two potentially destructive seismic events were recorded during this time (Figure 5):

- M6.1 - Central East Pacific Rise earthquake; recorded on March 22, 2020 at 22:38 UTC;
- M7.5 – Russia earthquake; recorded on March 25, 2020 at 02:49 UTC.

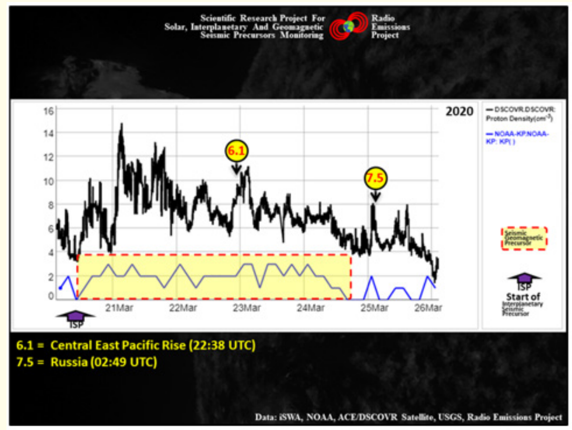

Figure 5: Variations in the ion density of the solar wind that preceded the M6+ global seismic activity of 22-25 March 2020. In the graph above was highlighted the close correlation found by the authors between solar activity (solar wind) and M6+ global seismic activity recorded between 22 and 25 March 2020. The vertical black arrows represent the time markers of the M6+ seismic events; the blue curve represents the variation of the Kp index; The black curve represents the variation of the proton density of the solar wind (p/cm^3) recorded through the Deep Space Climate Observatory (DSCOVR) Satellite, positioned in Lagrangian L1 orbit; the yellow area delimited by the dashed red line highlights the temporal position of the Seismic Geomagnetic Precursor (SGP) related to M6+ seismic event recorded between 22 and 25 March 2020 ; the vertical purple arrow, identified with the acronym "ISP", represents the beginning of the Interplanetary Seismic Precursor (ISP) related to the M6+ seismic events. Credits: USGS, NOAA, iSWA, ACE/DSCOVR Satellite, Radio Emissions Project.

Discussion

The variations in the density of the solar ion flux [4], due to the characteristics they have with respect to global seismic activity, have been called by the authors as "Interplanetary Seismic Precursors" (ISPs), i.e. phenomena of an electromagnetic nature and of solar origin related to seismic activity terrestrial that can be detected within interplanetary space. ISPs were first observed by the authors in 2011 when they began the first correlation studies between the Interplanetary Magnetic Field (IMF) and M6+ global seismic activity [20-23]. From the moment that the DSCOVR Satellite recorded the start of the increases in the proton density of the solar wind, to the moment that were recorded the M7+ seismic events considered in this study, the following time intervals have elapsed:

- M7.7 – Jamaica earthquake, recorded on January 28, 2020 at 19:10 UTC = 28 hours.
- M7.0 – Russia earthquake, recorded on February 13, 2020 at 10:33 UTC = 12 hours.
- M7.5 – Russia Earthquake, recorded on March 25, 2020 at 02:49 UTC = 112 hours.

But that is not all. About 15 hours before the M7.7 earthquake recorded in Jamaica on January 28, 2020, at 19:10 UTC, perturbations of the Earth's geomagnetic field were recorded (Figure 6); perturbations triggered by the interaction between the solar ion flux (Interplanetary Seismic Precursors or ISPs) and the Earth's magnetosphere. The same phenomenon was also observed with respect to the two M7+ earthquakes recorded in Russia:

- M7.0 earthquake, recorded on February 13, 2020 at 10:33 UTC: in this case, the geomagnetic perturbation preceded the earthquake by about 19 hours (Figure 7);
- M7.5 earthquake, recorded on March 25, 2020 at 02:49 UTC: in this case, the geomagnetic perturbation preceded the earthquake by about 39 hours (Figure 8).

These perturbations of the geomagnetic field are to be considered in all respects a Seismic Electromagnetic Precursors (SEPs), but since they are perturbations of the Earth's geomagnetic field that precede potentially destructive seismic events, the authors have defined them as "Seismic Geomagnetic Precursors" (SGPs). This type of correlation and the term "Seismic Geomagnetic Precursors" (SGPs) were presented by the authors to the international scientific community in 2013 [1,2,5] thanks to a large correlation study conducted by the same authors between January 1, 2012 and December 31, 2012 and to some instrumental observations made starting from 2009. No other team of researchers had obtained the same results until then.

From a predictive point of view, considering the ISPs and SGPs, the three strong earthquakes were preceded by electromagnetic phenomena with an advance including between:

- M7.7 earthquake = 28 and 15 hours;
- M7.0 earthquake = 19 and 12 hours;
- M7.5 earthquake = 112 and 39 hours.

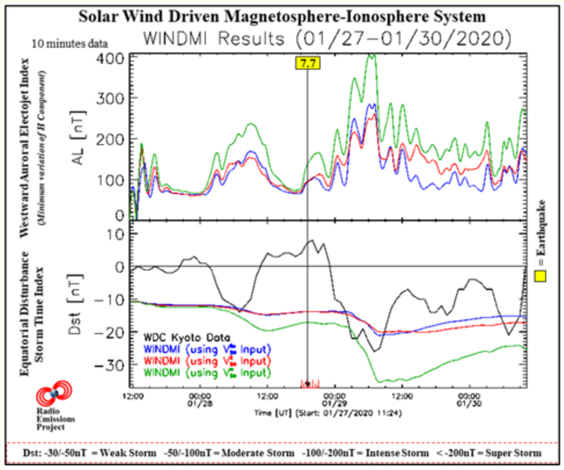

Figure 6: Correlation between WINDMI (Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere) and the M7.7 earthquake recorded in Jamaica on January 28, 2020. The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the Jamaican M7.7 earthquake occurred on January 28, 2020. The DST-Index is a direct measure of the Earth's geomagnetic horizontal (H) component variation due to the equatorial ring current, while the AL-Index (Auroral Lower) is at all times, the minimum value of the variation of the geomagnetic H component of the geomagnetic field recorded by observers of reference and provides a quantitative measure of global Westward Auroral Electroject (WEJ) produced by increased of ionospheric currents therein present. The WINDMI data analysis showed that the Jamaican earthquake occurred on January 28, 2020 was preceded by an increase of solar and geomagnetic activity. The black vertical arrow shows the temporal marker of the M7.7 Jamaican earthquake. Model developed by the Institute for Fusion Studies, Department of Physics, University of Texas at Austin.

The analysis of geomagnetic data (WINDMI) has once again confirmed the effectiveness of the seismic forecasting method developed by the authors which, it is right to reiterate it, is based on the analysis and observation of real physical phenomena of solar and geomagnetic nature and not on purely statistical data. This detail represents the great novelty introduced by the authors in the scientific research dedicated to global seismic prediction since 2013.

Through the figure 6-8 it is possible to understand that all the M7+ seismic events considered in this work occurred after an increase of DST index (also called "geomagnetic storm index"). The DST index is a direct measure of the intensity of the horizontal geomagnetic component "H" due to:

- Equatorial ring current;
- Transverse current to the tail;
- Magnetopause current;
- Partial loop current;
- Currents aligned to the field;

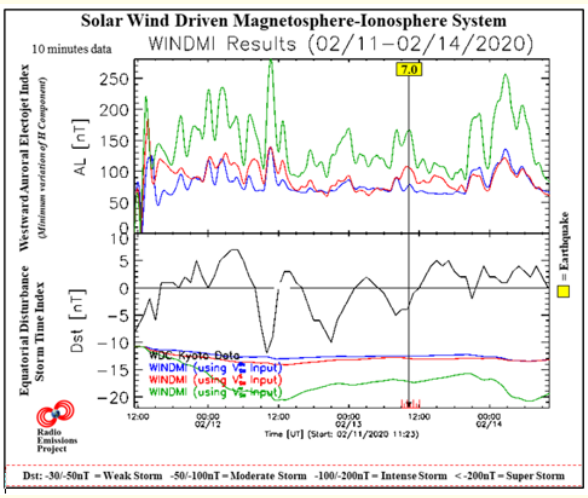

Figure 7: Correlation between WINDMI (Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere) and the M7.0 earthquake recorded in Russia on February 13, 2020. The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the Russian M7.0 earthquake occurred on February 13, 2020. The DST-Index is a direct measure of the Earth's geomagnetic horizontal (H) component variation due to the equatorial ring current, while the AL-Index (Auroral Lower) is at all times, the minimum value of the variation of the geomagnetic H component of the geomagnetic field recorded by observers of reference and provides a quantitative measure of global Westward Auroral Electroject (WEJ) produced by increased of ionospheric currents therein present. The WINDMI data analysis showed that the Russian earthquake occurred on February 13, 2020 was preceded by an increase of solar and geomagnetic activity. The black vertical arrow shows the temporal marker of the M7.0 Russian earthquake. Model developed by the Institute for Fusion Studies, Department of Physics, University of Texas at Austin.

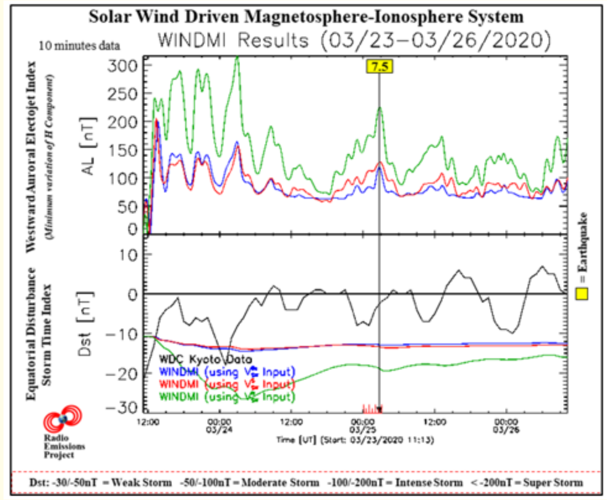

Figure 8: Correlation between WINDMI (Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere) and the M7.5 earthquake recorded in Russia on March 25, 2020. The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the Russian M7.5 earthquake occurred on March 25, 2020. The DST-Index is a direct measure of the Earth's geomagnetic horizontal (H) component variation due to the equatorial ring current, while the AL-Index (Auroral Lower) is at all times, the minimum value of the variation of the geomagnetic H component of the geomagnetic field recorded by observers of reference and provides a quantitative measure of global Westward Auroral Electroject (WEJ) produced by increased of ionospheric currents therein present. The WINDMI data analysis showed that the Russian earthquake occurred on March 25, 2020 was preceded by an increase of solar and geomagnetic activity. The black vertical arrow shows the temporal marker of the M7.5 Russian earthquake. Model developed by the Institute for Fusion Studies, Department of Physics, University of Texas at Austin.

And allows to evaluate the level of geomagnetic storm on a global scale. It has been known for some time that the horizontal geomagnetic component "H" (i.e. that which refers to the intensity of the earth's geomagnetic field measured on the axis directed towards the magnetic North Pole) decreases in the course of geomagnetic storms, and that its intensity it goes up gradually [17,18,30].

By analyzing the variation curves of AL index (Aurora Lower index: minimum value of the variation of the H component of the Earth's magnetic field) it is possible to observe that the two Russian earthquakes (M7.0 and M7.5) were recorded during a peak of increase of AL index, while the Jamaican M7.7 earthquake occurred after the start of a large increase of AL index. This is explained by the impact that solar activity (solar wind) has on the Earth's magnetosphere: it is evident that if the three M7+ seismic events considered in this study are correlated to an increase in the density of the solar ion flux, they must also be correlated to an increase in the Earth's geomagnetic activity since the increases in the density of the solar wind recorded at the Lagrange point L1 always go towards the Earth, colliding with the Earth's magnetosphere and thus generating perturbations of the Earth's geomagnetic field. Certainly, the higher the density level of the solar ion flux, the greater the perturbations induced by the impact of the solar wind on the Earth's magnetosphere and vice versa.

This work confirmed that there is a close correlation between solar activity and global M7+ seismic activity. The phenomena responsible for this type of interaction are of electromagnetic type: on the one hand we find the solar ion flux (the proton density of the solar wind), while on the other hand we find the Earth's geomagnetic field. When these two phenomena interact, perturbations of the Earth's geomagnetic field are produced which are in turn closely related to the M6+ global seismic activity. The authors theorized that variations in the Earth's geomagnetic field can have a significant impact on the crystal grid of the rocks included in the fault plane through the inverse piezoelectric effect [3] and through the phenomenon of magnetostriction: in practice, the crystal grid modify their shape (elastic deformation) suddenly when they are crossed by an electromagnetic field that changes suddenly, altering the static balance of the faults and stimulating the production of the seismic event. In this case, the electromagnetic source is provided by the variations of the Earth's geomagnetic field which, obviously, are influenced by solar activity, that is, by the variations in the density of the solar wind ion flux (proton density): an inexhaustible source. In addition to this, it would be possible theoretically to consider another phenomenon of an electromagnetic nature capable of altering the static balance of faults through the variation of the Earth's geomagnetic field: the Lorentz force, that is the force exerted on a electrically charged object due to the effect of an electromagnetic field that permeates it. The creation of microfractures in the Earth's crust following the accumulation of tectonic stress could lead to the formation of vast and dense electronic clouds which, under the influence of the Earth's geomagnetic field, could generate forces capable of altering the static balance of the faults.

As regards the type of data used, the authors were able to verify that during the solar minimum it is more convenient to measure the density variation of the solar ion flux in p/cm3 compared to p/(cm2-sec-ster-MeV) and vice versa, since the second type of measurement does not produce significantly appreciable readings during the solar minimum.

Conclusion

In conclusion, it can be stated (and confirmed) that there is a close correlation between the variations in the density of the solar ion flux (proton density), the Earth's geomagnetic activity and the potentially destructive seismic activity that is recorded on a global scale. The processes that regulate this interaction are not yet fully known but it is likely that the inverse piezoelectric effect and magnetostriction play a significant role in the seismogenesis related to variations in the Earth's geomagnetic field. Currently, by monitoring solar activity, it is possible to understand with a few days in advance (on average) when a resumption of seismic activity M6+ is expected on our planet: this is an important discovery both on a predictive and scientific level that the authors have presented to the international scientific community in 2013 and repeated several times over the years. The authors are convinced that it would be convenient to use this new seismic forecasting method as an indicator capable of establishing an increase in seismic risk on a global scale, in fact this method affects the probability of occurrence of the seismic event.

Acknowledgements

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