Space weather and geomagnetic activity related to the Japanese M7.1 earthquake recorded on February 13, 2021

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Abstract

On February 13, 2021 at 14:07:50 UTC, an M7.1 earthquake was recorded in Japan at a depth of 49.9 km. The analysis of solar activity and terrestrial geomagnetic activity allowed the authors to verify that the M7.1 Japanese earthquake was preceded by an increase in solar activity which subsequently produced an increase in terrestrial geomagnetic activity: phenomena of electromagnetic nature that the authors have related to the M6+ global seismic activity since 2011.

Keywords: proton density increase, seismic precursors, solar activity, geomagnetic activity.

Introduction

Japan is located in a geographic area influenced, from a tectonic point of view, by North America plate, Pacific plate, Philippine Sea plate, and Eurasia plate. This feature makes Japan one of the most seismically active areas and the highest seismic risk on the planet. Between 2012 and 2020, the authors highlighted that the seismic events recorded in Japan are closely related to solar activity and terrestrial geomagnetic activity [1] [2] [5] [6] [7] [12] [13] [19] [20] [21] [23] confirming the results obtained between 2012 and 2021: potentially destructive seismic events that are recorded on a global scale are always preceded by an increase in the density of the solar ion flux (especially the proton density) and by a consequent increase in the Earth's geomagnetic activity [1-24]. On February 13, 2021 at 14:07:50 UTC, an M7.1 earthquake was recorded in Japan (**Fig. 1**) just during the terminal phase of an increase in the density of the solar ion flux which also generated an increase in geomagnetic terrestrial activity.

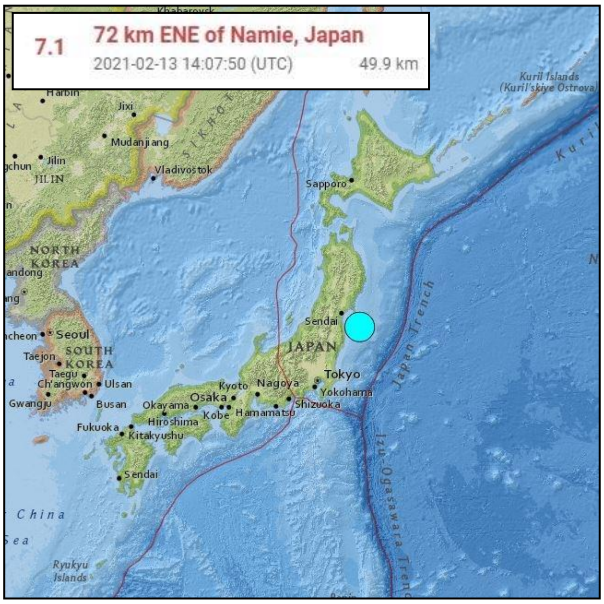

Fig. 1 – Epicenter of the M7.1 Japanese earthquake. The image above shows the map of Japan and the epicenter of the M7.1 earthquake recorded on 13 February 2021 at 14:07:50 UTC, at a depth of 49.9 km.
Credits: USGS, Radio Emissions Project.

Data analysis

Thanks to the data provided by the DSCOVR Satellite located in the Lagrangian orbit L1, on February 10, 2021 at 20:30 UTC the authors started following the evolution of a solar wind proton density increase which ended on February 14, 2021 at 02:00 UTC and whose maximum peak was reached on February 13, 2021 at 01:23 UTC. Four potentially destructive seismic events were recorded during this proton density increase (**Fig. 2**):

1. M6.2 Loyalty Islands earthquake, recorded on February 10, 2021 at 21:24 UTC.
2. M6.0 Loyalty Islands earthquake, recorded on February 11, 2021 at 06:52 UTC.
3. M7.1 Japan earthquake, recorded on February 13, 2021 at 14:07 UTC.
4. M6.0 Papua New Guinea earthquake, recorded on February 13, 2021 at 15:33 UTC.

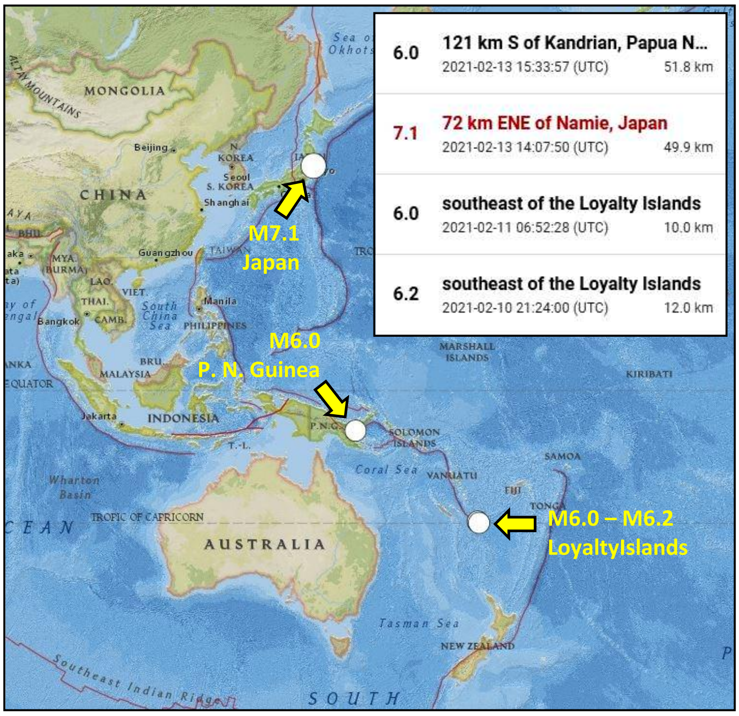

Fig. 2 – Potentially destructive seismic events related to the proton increase of 10-14 February 2021. The image shows the epicenters of potentially destructive earthquakes related to the proton increase recorded between 10 and 14 February 2021. Credits: USGS, Radio Emissions Project.

Analyzing the temporal data of the four seismic events with the space weather data provided by DSCOVR Satellite between 10 and 14 February 2021, the authors were able to calculate the time intervals recorded between the start of the proton increment (Interplanetary Seismic Precursor) and the four M6+ seismic events:

1. M6.2 Loyalty Islands earthquake, recorded on February 10, 2021 at 21:24 UTC ≈ **1** hour.
2. M6.0 Loyalty Islands earthquake, recorded on February 11, 2021 at 06:52 UTC ≈ **10** hours.
3. M7.1 Japan earthquake, recorded on February 13, 2021 at 14:07 UTC ≈ **66** hours.
4. M6.0 Papua New Guinea earthquake, recorded on February 13, 2021 at 15:33 UTC ≈ **67** hours.

The average time interval calculated by analyzing the seismic activity and the solar activity that occurred between 1 January 2012 and 18 February 2021 is equal to 108.8 hours: the average was calculated by analyzing 1192 M6+ seismic events that occurred in the same period. Among the four potentially destructive seismic events related to the proton increase that occurred between 10 and 14 February 2021, the authors focused their attention on the M7.1 Japanese earthquake as it is of greater magnitude than the others and occurred immediately after an important geomagnetic increase (Seismic Geomagnetic Precursor) recorded between 12:00 UTC on February 12, 2021 and 20:00 UTC on February 13, 2021, an increase that was associated with a weak geomagnetic storm (Seismic Geomagnetic Precursor) (**Fig. 4**).

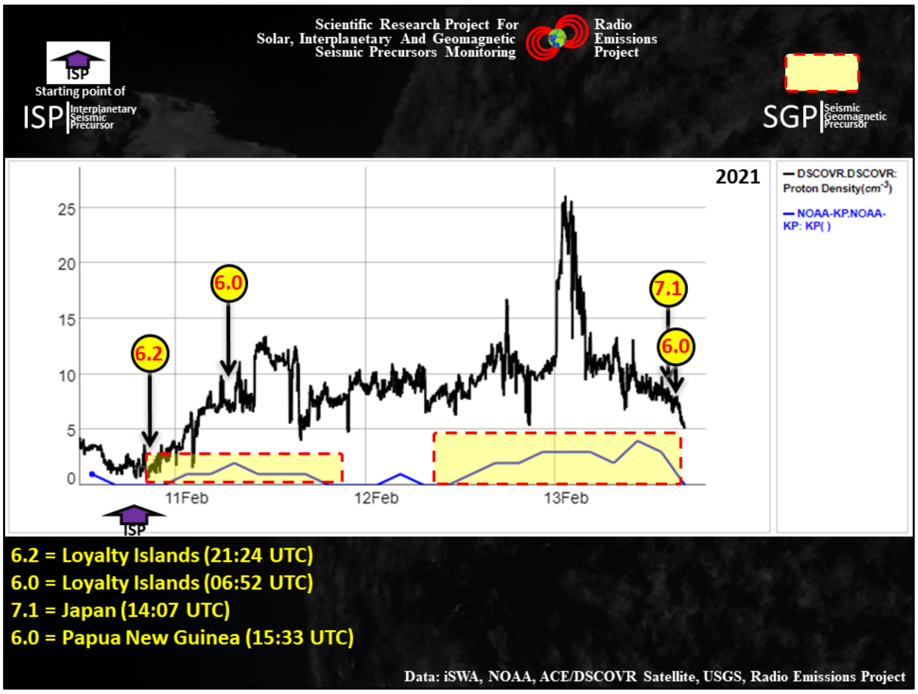

Fig. 3 – Interplanetary and Geomagnetic Seismic Precursors. The graph above shows the temporal markers (black arrows) of the four related seismic events at solar wind proton density increase (Interplanetary Seismic Precursor) recorded between 10 and 24 February 2021. The proton increase produced two geomagnetic increases (Seismic Geomagnetic Precursors) which have been highlighted within the yellow areas. Credits: USGS, Radio Emissions Project.

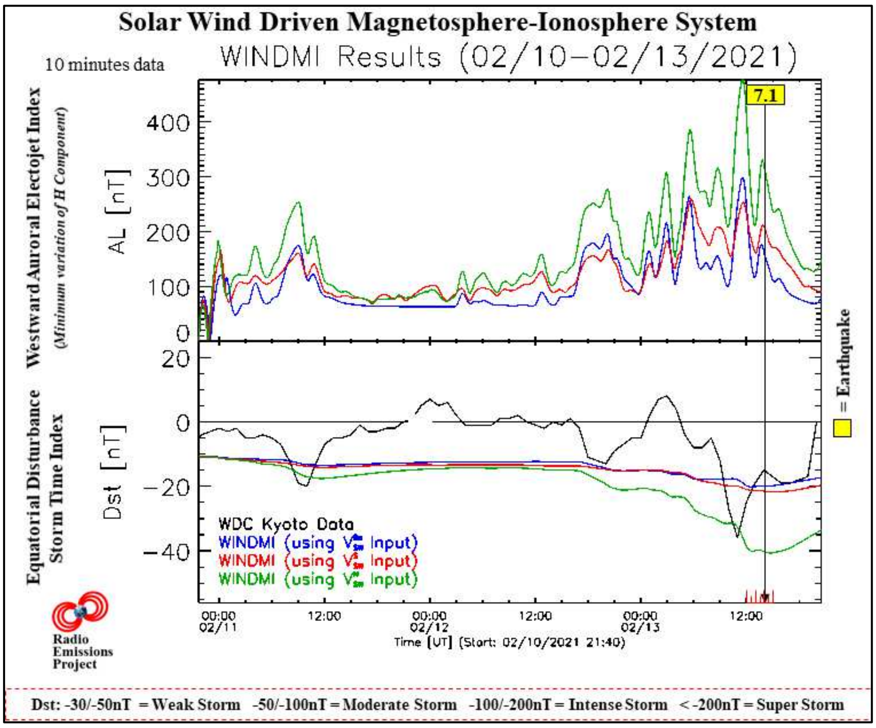

Fig. 4 – Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere (WINDMI). The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the Japanese M7.1 earthquake occurred on February 13, 2021 (the time marker of the earthquake is indicated by a vertical black line). 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. Model developed by the Institute for Fusion Studies, Department of Physics, University of Texas at Austin. Credits: iSWA, USGS, Radio Emissions Project.

To confirm the correlation found between solar activity and the M7.1 Japanese earthquake, the authors identified a disturbance of the Interplanetary Magnetic Field (IMF) (**Fig. 4**) that preceded the seismic event by about 18 hours. Furthermore, analyzing the data on the speed of the solar wind, the authors identified a rapid increase in the speed of the solar ion flux that preceded the M7.1 Japanese earthquake by about 24 hours (**Fig. 5**). Both of these phenomena are manifestations of solar electromagnetic activity that have been defined by the authors as "Interplanetary Seismic Precursors" or ISP, since they precede seismic events of high magnitude that are recorded on a global scale.

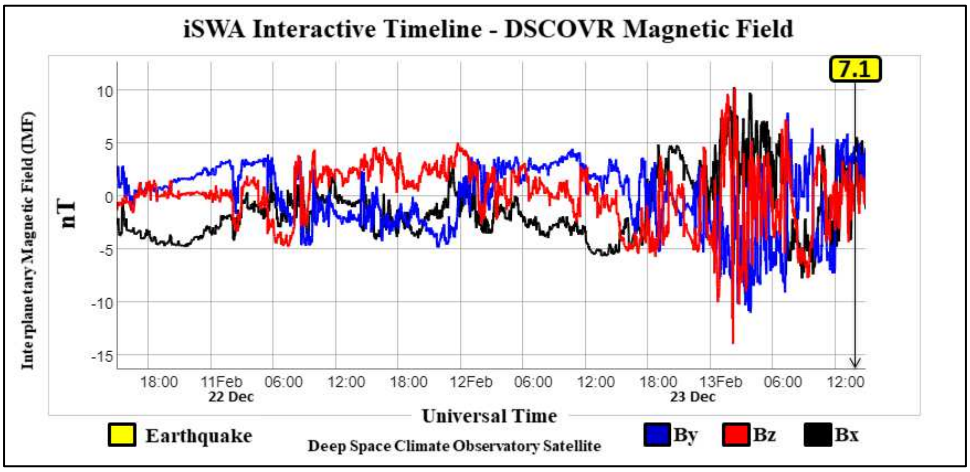

Fig. 4 – Interplanetary Magnetic Field (IMF) related to M7.1 Japan earthquake. The graph above shows a disturbance of Interplanetary Magnetic Field (IMF) which preceded the Japanese M7.1 earthquake recorded on February 13, 2021 by almost 18 hours (black vertical arrow).
Credits: iSWA, USGS, Radio Emissions Project.

Fig. 5 – Solar wind velocity related to M7.1 Japan earthquake. The graph above shows a rapid increase in the speed of the solar wind that preceded the Japanese M7.1 earthquake recorded on February 13, 2021 (black vertical arrow).
Credits: iSWA, USGS, Radio Emissions Project.

Perturbations of Interplanetary Magnetic Field (IMF) and increases in the speed of the solar ion flow explain, through the coupling function between solar activity and the terrestrial magnetosphere, why an increase in AL Index and DST Index was recorded (**Fig. 4**). From a temporal point of view, solar activity and terrestrial geomagnetic activity show a series of electromagnetic phenomena connected to each other up to the seismic event related to them. By following this chain of electromagnetic events backwards, it was possible to identify a first seismic precursor of the electromagnetic type responsible for the variations in the density of the solar ion flux present in interplanetary space; the authors called this seismic precursor the "Solar Seismic Precursor" or SSP. This term refers to electromagnetic phenomena visible on the photosphere, in the chromosphere and in the solar corona that can also be monitored from the Earth:

a) coronal hole and high speed solar wind (HSSW);
b) sunspots and magnetic loops;
c) solar flare and coronal mass ejections (CMEs);

Conclusions

The monitoring of solar activity combined with the monitoring of the Earth's geomagnetic activity continues to provide important and evident indications about the close correlation that exists between electromagnetic phenomena of solar origin and potentially destructive seismic events that are recorded on our planet [23] [24]. The solar and geomagnetic data that the authors correlated to the Japanese M7.1 earthquake recorded on February 13, 2021 provide a further indication of the potential (in terms of seismic prediction) that monitoring of solar activity and terrestrial geomagnetic activity have. Although the first important studies on this type of correlation were carried out between 1960 and 1970 [25] [26] [27] [28], we can certainly affirm that the basis of a new and innovative seismic forecasting method based on the monitoring and analysis of solar activity and terrestrial geomagnetic activity were built by the authors thanks to the studies conducted in this research area from 2012 to today [24] and thanks to the development of technology dedicated to crustal diagnosis [24].

Credits

[1] G. Cataldi, D. Cataldi, V. Straser. (2013). Variations Of Terrestrial Geomagnetic Activity Correlated To M6+ Global Seismic Activity. EGU (European Geosciences Union) 2013, General Assembly, Seismology Section (SM3.1), Earthquake precursors, bio-anomalies prior to earthquakes and prediction, Geophysical Research Abstracts, Vol. 15. EGU2013-2617, Vienna, Austria. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[2] G. Cataldi, D. Cataldi and V. Straser. (2014). Earth's magnetic field anomalies that precede the M6+ global seismic activity. European Geosciences Union (EGU) General Assembly 2014, Geophysical Research Abstract, Vol. 16, EGU2014-1068, Vienna, Austria. Natural Hazard Section (NH4.3), Electro-magnetic phenomena and connections with seismo-tectonic activity, Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[3] D. Cataldi, G. Cataldi and V. Straser. (2014). Variations of the Electromagnetic field that preceded the Peruvian M7.0 earthquake occurred on September 25, 2013. European Geosciences Union (EGU) General Assembly 2014, Geophysical Research Abstract, Vol. 16, EGU2014-1075, Natural Hazard Section (NH4.3), Electro-magnetic phenomena and connections with seismo-tectonic activity, Vienna, Austria. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[4] T. Rabeh, G. Cataldi, V. Straser. (2014). Possibility of coupling the magnetosphere–ionosphere during the time of earthquakes. European Geosciences Union (EGU) General Assembly 2014, Geophysical Research Abstract, Vol. 16, EGU2014-1067, Vienna, Austria. Natural Hazard Section (NH4.3), Electro-magnetic phenomena and connections with seismo-tectonic activity. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[5] V. Straser, G. Cataldi. (2014). Solar wind proton density increase and geomagnetic background anomalies before strong M6+ earthquakes. Space Research Institute of Moscow, Russian Academy of Sciences, MSS-14. 2014. Moscow, Russia. pp280-286.

[6] V. Straser, G. Cataldi, D. Cataldi. (2015). Radio-anomalies: tool for earthquakes and tsunami forecasts. European Geosciences Union (EGU) General Assembly 2015, Natural Hazard Section (NH5.1), Sea & Ocean Hazard - Tsunami, Geophysical Research Abstract, Vol. 17, Vienna, Austria. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[7] V. Straser, G. Cataldi. (2015). Solar wind ionic variation associated with earthquakes greater than magnitude M6.0. New Concepts in Global Tectonics Journal, V. 3, No. 2, June 2015, Australia. P.140-154.

[8] G. Cataldi, D. Cataldi, V. Straser. (2015). Solar wind proton density variations that preceded the M6+ earthquakes occurring on a global scale between 17 and 20 April 2014. European Geosciences Union (EGU) General Assembly 2015, Vienna, Austria. Natural Hazard Section (NH5.1), Sea & Ocean Hazard - Tsunami, Geophysical Research Abstract, Vol. 17, EGU2015-4157-2, Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[9] G. Cataldi, D. Cataldi, V. Straser. (2015). Solar wind ion density variations that preceded the M6+ earthquakes occurring on a global scale between 3 and 15 September 2013. European Geosciences Union (EGU) General Assembly 2015, Geophysical Research Abstract, Vol. 17, EGU2015-4581, Vienna, Austria. Natural Hazard Section (NH5.1), Sea & Ocean Hazard - Tsunami, Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[10] G. Cataldi, D. Cataldi, V. Straser. (2015). Solar wind proton density variations that preceded the M6,1 earthquake occurred in New Caledonia on November 10, 2014. European Geosciences Union (EGU) General Assembly 2015, Geophysical Research Abstract, Vol. 17, EGU2015-4167, Vienna, Austria. Natural Hazard Section (NH5.1), Sea & Ocean Hazard - Tsunami, Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[11] V. Straser, G. Cataldi, D. Cataldi. (2015). Solar wind ionic and geomagnetic variations preceding the Md8.3 Chile Earthquake. New Concepts in Global Tectonics Journal, V. 3, No. 3, September 2015, Australia. P.394-399.

[12] G. Cataldi, D. Cataldi, V. Straser. (2016). Solar activity correlated to the M7.0 Japan earthquake occurred on April 15, 2016. New Concepts in Global Tectonics Journal, V. 4, No. 2, pp202-208, June 2016.

[13] G. Cataldi, D. Cataldi, V. Straser. (2016). Tsunami related to solar and geomagnetic activity. European Geosciences Union (EGU) General Assembly 2016, Natural Hazard Section (NH5.6), Complex modeling of earthquake, landslide, and volcano tsunami sources. Geophysical Research Abstract, Vol. 18, EGU2016-9626, Vienna, Austria. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[14] G. Cataldi, D. Cataldi, V. Straser. (2017). SELF-VLF electromagnetic signals and solar wind proton density variations that preceded the M6.2 Central Italy earthquake on August 24, 2016. International Journal of Modern Research in Electrical and Electronic Engineering, Vol. 1, No. 1, 1-15. DOI: 10.20448/journal.526/2017.1.1/526.1.1.15.Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[15] G. Cataldi, D. Cataldi, V. Straser. (2017). Solar and Geomagnetic Activity Variations Correlated to Italian M6+ Earthquakes Occurred in 2016. European Geosciences Union (EGU), General Assembly 2017. Geophysical Research Abstracts Vol. 19, EGU2017-3681, 2017. Seismology (SM1.2)/Natural Hazards (NH4.7)/Tectonics & Structural Geology (TS5.5) The 2016 Central Italy Seismic sequence: overview of data analyses and source models. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[16] G. Cataldi, D. Cataldi, V. Straser. (2017). Solar wind proton density increase that preceded Central Italy earthquakes occurred between 26 and 30 October 2016. European Geosciences Union (EGU), General Assembly 2017. Geophysical Research Abstracts Vol. 19, EGU2017-3774, 2017. Seismology (SM1.2)/Natural Hazards (NH4.7)/Tectonics & Structural Geology (TS5.5) The 2016 Central Italy Seismic sequence: overview of data analyses and source models. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[17] V. Straser, G. Cataldi, D. Cataldi. (2017). Solar and electromagnetic signal before Mexican Earthquake M8.1, September 2017. New Concepts in Global Tectonics Journal, V. 5, No. 4, December 2017, pp. 600-609.

[18] G. Cataldi, D. Cataldi, V. Straser. (2017). Solar and Geomagnetic Activity Variations Correlated to Italian M6+Earthquakes Occurred in 2016. EGU General Assembly 2017. EGU2017-3681, Vol. 19.

[19] G. Cataldi, D. Cataldi, V. Straser. (2019). Solar wind ionic density variations related to M6+ global seismic activity between 2012 and 2018. European Geosciences Union (EGU) General Assembly 2019, Short-term Earthquake Forecast (StEF) and multy-parametric time-Dependent Assessment of Seismic Hazard (t-DASH) (NH4.3/AS4.62/EMRP2.40/ESSI1.7/Gi2.13/SM3.9), General Contribution on Earthquakes, Earth Structure, Seismology (SM1.1), Geophysical Research Abstract, Vol. 21, EGU2019-3067, 2019, Vienna, Austria. Harvard-Smithsonian Center for Astrophysics, High Energy Astrophysics Division, SAO/NASA Astrophysics Data System.

[20] G. Cataldi. (2020). Precursori Sismici – Monitoraggio Elettromagnetico. Kindle-Amazon, ISNB: 9798664537970. ASIN Code: B08CPDBGX9.

[21] G. Cataldi, D. Cataldi, V. Straser. (2019). Wolf Number Related To M6+ Global Seismic Activity. New Concepts in Global Tectonics Journal, Volume 7, Number 3, December 2019, pp. 178-186.

[22] V. Straser, G. Cataldi, D. Cataldi. (2020). The Space Weather Related to the M7+ Seismic Activity Recorded on a Global Scale between 28 January and 25 March 2020. Acta Scientific Agriculture 4.12 (2020): 55-62.

[23] G. Cataldi, V. Straser, D. Cataldi. (2020). Space Weather related to potentially destructive seismic activity recorded on a global scale. New Concepts in Global Tectonics Journal. Vol.8, No.3, pp. 233-253, December 2020. ISSN 2202-0039.

[24] G. Cataldi. (2021). Radio Emissions Project – A new approach to seismic prediction. Kindle-Amazon, ISNB: 9798709593411.

[25] P. Velinov. (1975). The effect of solar activity on geophysical processes. Bu/g Geofiz. Spis., vol. 1, pp. 51-77.

[26] I. F. Simpson. (1968). Solar activity as a triggering mechanism for earthquakes. Earth and Planet, Sci. Letter, 1968, v.3, No.5, pp. 417-425.

[27] Y. D. Kalinin. (1974). Solar conditionality of days duration change and seismic activity. Krasnoyarsk, Institute of Physics of Siberian Department of USSR Academy of Science, 1974, p.23.

[28] I. K. Gribbin. (1974). The next California earthquake. New York. Walker, 1974, p. 136.