Space weather and geomagnetic activity related to the Vanuatu M6.3 earthquake recorded on March 20, 2019

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Abstract

On March 20, 2019 at 15:23:58 UTC, an M6.3 earthquake was recorded in Vanuatu at a depth of 119 km. The analysis of solar activity and terrestrial geomagnetic activity allowed the authors to verify that the M6.3 Vanuatu earthquake was preceded by an increase in solar activity (solar wind proton density increase; Interplanetary Seismic Precursor) and in terrestrial geomagnetic activity (Seismic Geomagnetic Precursor). This type of correlation was first observed by the authors in 2011 and is currently related to all potentially destructive seismic events recorded on a global scale from January 1, 2012 to date.

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

Introduction

The eastern edge of the Australian plate is one of the most seismically active areas in the world due to the high convergence rates between the Australian and Pacific plates. In this tectonic context, on March 20, 2019 at 15:23:58 UTC, an M6.3 earthquake was recorded in Vanuatu (**Fig. 1**).

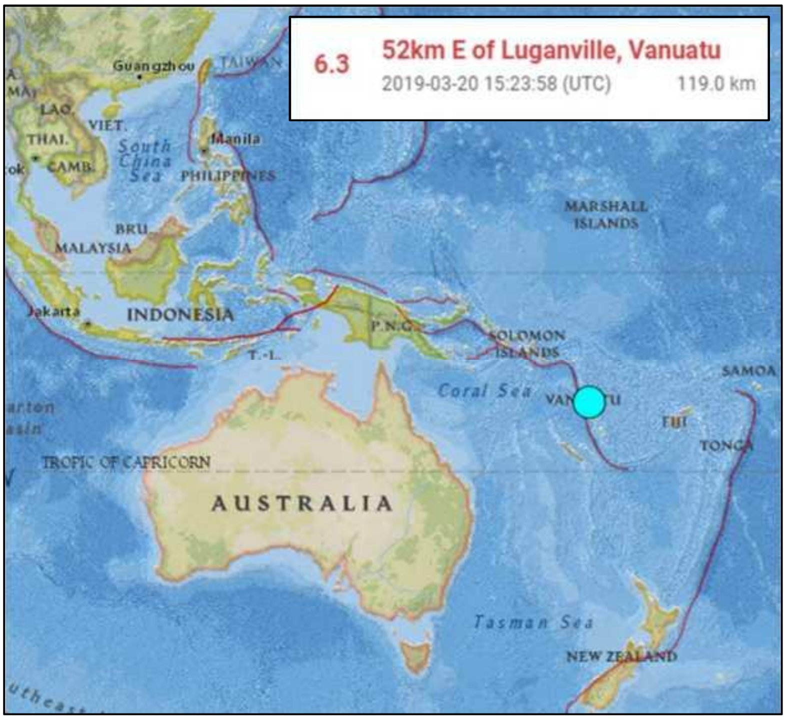

Fig. 1 – Epicenter of the M6.3 Vanuatu earthquake. The image above shows the map of the M6.3 Vanuatu earthquake epicenter recorded on March 20, 2019 at 15:23:58 UTC and at a depth of 119 km. Credits: USGS, Radio Emissions Project.

The monitoring of solar activity and terrestrial geomagnetic activity allowed the authors to verify that the potentially destructive seismic activity that is recorded on a global scale is always preceded by a solar wind proton density increase and, due to the impact that has the solar wind on the Earth's magnetosphere, also by a consequent increase in the Earth's geomagnetic activity [1-24]. In this work, the results of the close correlation that the authors found between the M6.3 earthquake and solar and geomagnetic activity will be presented.

Data analysis

Analyzing the data on the modulation of the solar ion flux density provided by DSCOVR Satellite (located in the Lagrangian point L1) between 17 and 21 March 2019, the authors found that the Vanuatu M6.3 earthquake was preceded by a major solar wind proton density increase which started on March 17, 2019 at 11:30 and ended on March 21, 2019 at 12:00 UTC: the solar wind proton density increase preceded the Vanuatu M6.3 seismic event by approximately 76 hours. The maximum increment of protonic density was recorded on March 19, 2019 at 08:23 UTC, and preceded the seismic event by 17 hours (**Fig. 2**).

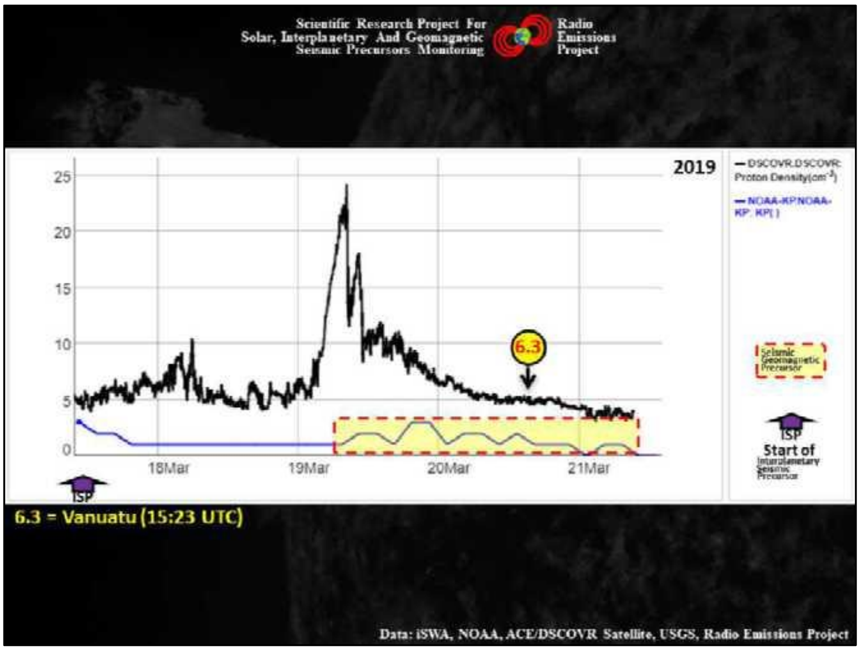

Fig. 2 – Interplanetary and Geomagnetic Seismic Precursors related to Vanuatu M6.3 earthquake. The graph above shows the variation curves of the solar wind proton density (black curve) and the geomagnetic activity (blue curve, highlighted by the yellow area) on which the time marker of Vanuatu M6.3 earthquake (recorded on March 20, 2019 at 15:23 UTC) has been superimposed. Credits: USGS, Radio Emissions Project.

The beginning of the proton increase was identified by detecting the lower level of proton density present on the variation curve: this can correspond to the basal level present in the interplanetary medium during solar quiet, or it can correspond to the variation line present between two close increases and therefore, it may also not correspond to the actual basal level. The studies conducted by the authors also highlighted that the time interval that separates the seismic event from the starting point of proton density increase can undergo variations in relation to the type of measurement that is taken as a reference: the measurement in p/cm^3 generally determines time intervals earlier than the measurement in p/(cm^2-sec-ster-MeV). Furthermore, other differences can be determined by taking as reference a certain fraction of protons energy respect that other [20]. The average time interval (which separates the solar wind proton density starting point and the seismic event) calculated by analyzing the seismic activity and the solar activity that occurred between January 1, 2012 and March 4, 2021 is equal to 108.8 hours: the average was calculated by analyzing 1193 M6+ seismic events that occurred in the same period.

Other important results were obtained by analyzing the Earth's geomagnetic activity that preceded the M6.3 earthquake (**Fig. 3**): confirming the solar wind proton density increase, the Vanuatu M6.3 earthquake was preceded by an evident increase in intensity of the Earth's magnetic field measured on the vector component "H" which touched 330nT; while a second increase in Earth's geomagnetic activity accompanied the M6.3 earthquake. The main geomagnetic increase preceded the Vanuatu M6.3 earthquake by about 30 hours.

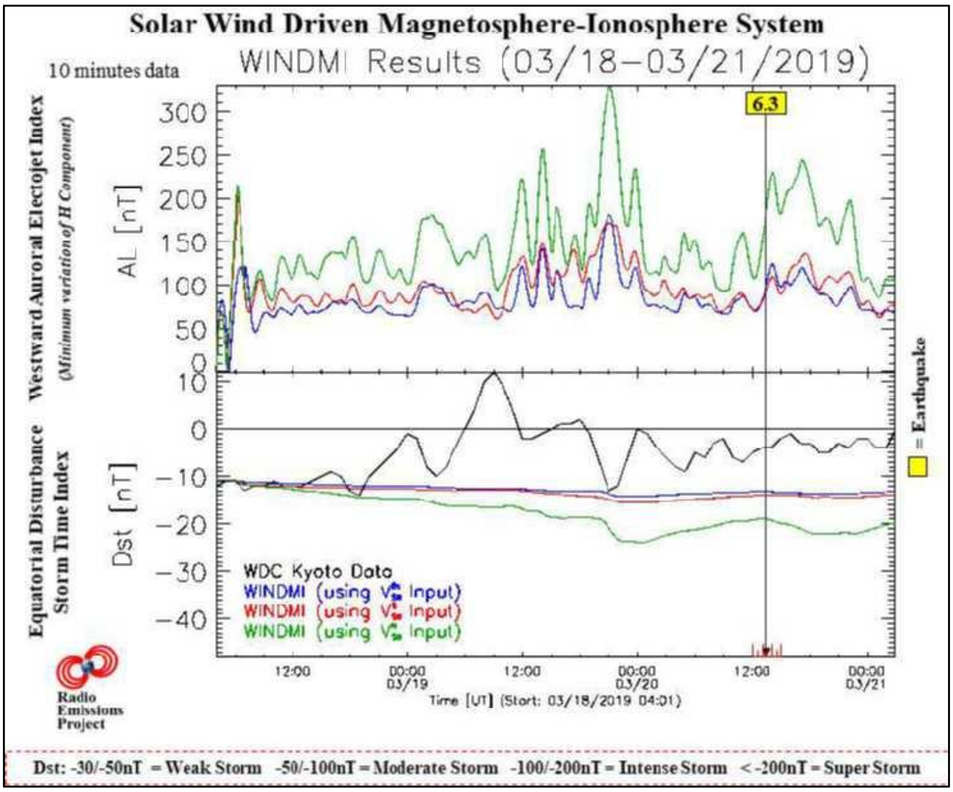

Fig. 3 – Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere (WINDMI). The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the Vanuatu M6.3 earthquake occurred on March 20, 2019 (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.

In addition, the curve relating to the DST Index showed a slight decline about 17 hours before the seismic event M6.3 confirming the presence of a pre-seismic geomagnetic perturbation.

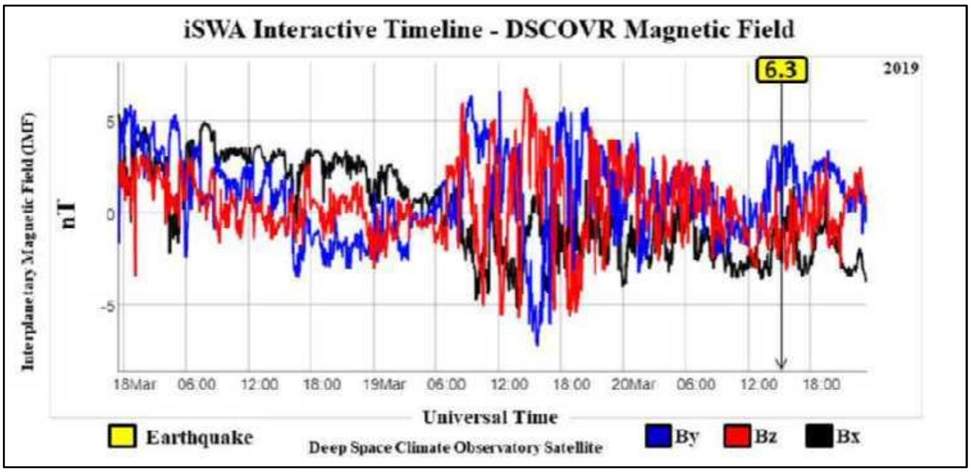

Fig. 4 – Interplanetary Magnetic Field (IMF) related to M7.1 Japan earthquake. The graph above shows a disturbance of Interplanetary Magnetic Field (IMF) which preceded the Vanuatu M6.3 earthquake recorded on March 20, 2019 (black vertical arrow) by almost 33 hours. Credits: iSWA, USGS, Radio Emissions Project.

Further confirmation of the observed correlation between the variation of the solar ion flux density and the M6.3 seismic event can be observed by the variation of Interplanetary Magnetic Field (**Fig. 4**): the potentially destructive earthquake was preceded by a perturbation of Interplanetary Magnetic Field which occurred about 33 hours before the earthquake; while a second and slight increase accompanied the seismic event.

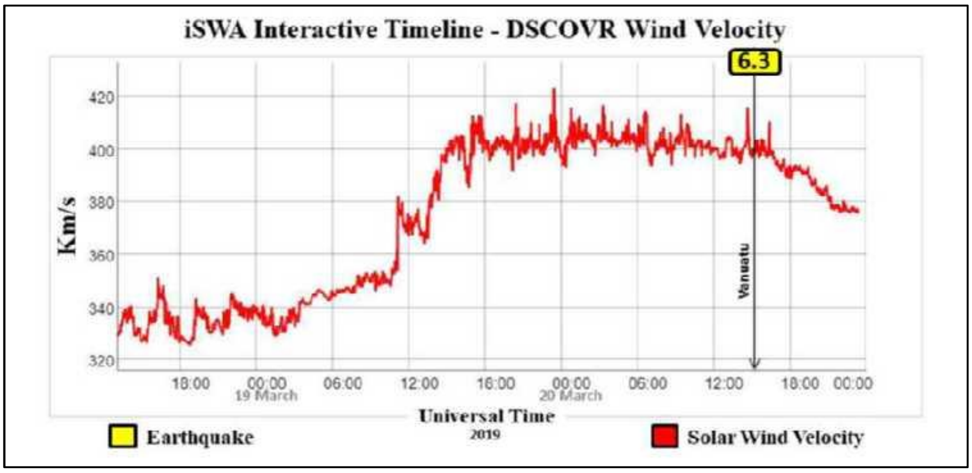

Fig. 5 – Solar wind velocity related to Vanuatu M6.3 earthquake. The graph above shows a rapid increase in the speed of the solar wind that preceded the Vanuatu M6.3 earthquake recorded on March 20, 2019 (black vertical arrow). Credits: iSWA, USGS, Radio Emissions Project.

A perturbation of Interplanetary Magnetic Field (IMF) is usually associated with an increase in the speed of the solar wind: the electrically charged particles that compose it, having a greater speed, determine a greater magnetic field in interplanetary space. Thanks to this electromagnetic mechanism, it is also possible to correlate potentially destructive seismic activity at solar wind velocity increase (**Fig. 5**), but this does not always happen. An increase in solar wind speed preceded the Vanuatu M6.3 earthquake by approximately 36 hours (**Fig. 5**).

Conclusions

Over the last ten years, the authors were able to identify a "certain" earthquake precursor that is able to predict when a resumption of M6+ global seismic activity is expected on our planet: we are talking about the increases in the proton density of the solar wind. The correlation data that have been presented in this work regarding the M6.3 earthquake recorded in Vanuatu in 2019 are only a very small part of the data related to the 1193 M6+ seismic events recorded on a global scale between January 1, 2012 and March 4, 2021 (corresponding to 100% of the M6+ seismic events recorded on a global scale in the same period): seismic events that were preceded by a solar wind proton density increase [5] [7] [8] [9] [10] [11] [12] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [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.