Space weather related to M6+ potentially destructive seismic events recorded on a global scale between 13 and 16 March 2022

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Abstract

Between 13 and 16 March 2022, four potentially destructive earthquakes were recorded on a global scale (M6.4 Philippines earthquake; M6.7 Indonesia earthquake; M6.0 Japan earthquake; M7.3 Japan earthquake). The authors, analyzing the conditions of the space weather, found that the four seismic events occurred during an evident and important increase in the proton density of the solar wind: a correlation that the authors first observed in 2011.

Keywords: space weather, seismic precursors, potentially destructive seismic events, M6+, solar wind proton density variation.

Introduction

The studies conducted by the authors on solar activity and global M6+ seismic activity between 2012 and 2021 made it possible to establish that the potentially destructive seismic activity that occurs on Earth is always preceded by an increase in the solar proton flux [1-37]. This evidence was also confirmed in 2022. This work will present the results obtained from the analysis of solar activity that preceded the potentially destructive seismic activity (M6+) between 13 and 16 March 2022 (**Fig. 1**).

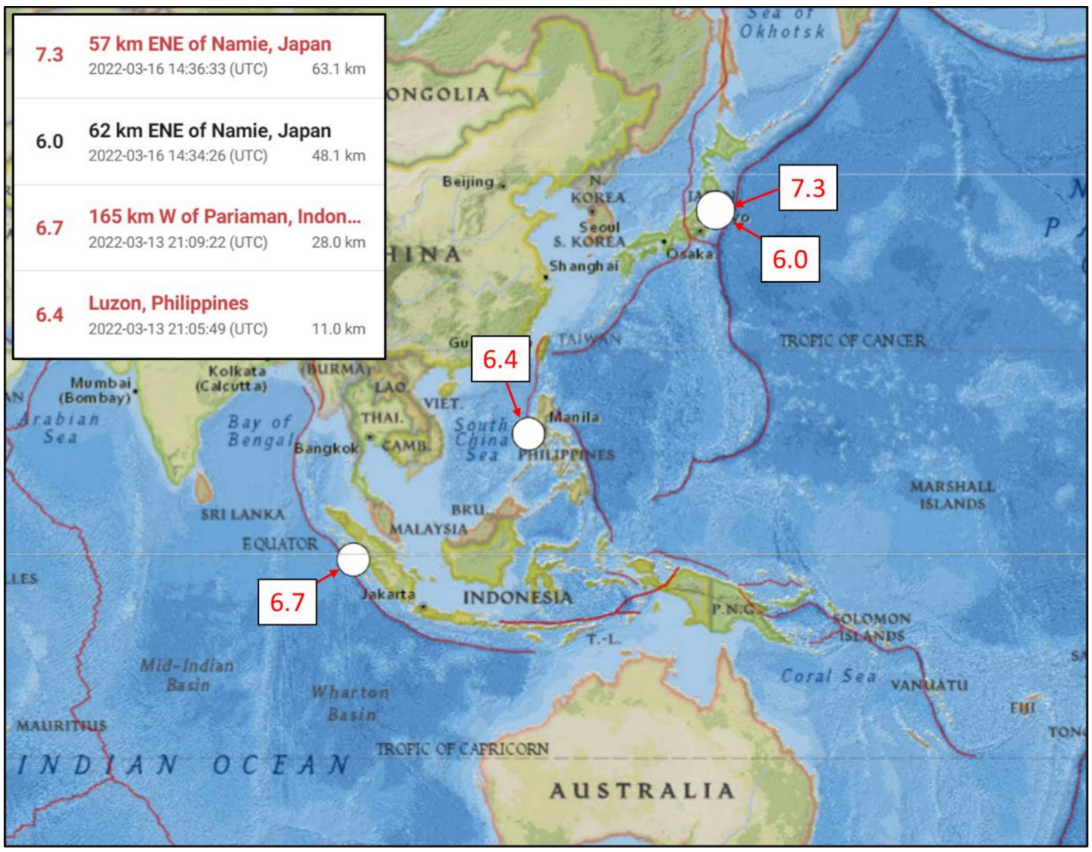

Fig. 1 – Seismic epicenters of M6+ seismic activity recorded between 13 and 16 March 2022. *The image above shows the position of the M6+ seismic epicenters recorded between 13 and 16 March 2022. Credits: Radio Emissions Project, USGS.*

Methods and data

To understand if the potentially destructive seismic activity recorded between 13 and 16 March 2022 was related to solar activity, the authors analyzed the modulation of solar ion flux between 12 and 17 March 2022 using solar ion flux data provided by Advanced Composition Explorer (ACE) satellite and taking as reference the following proton energy fractions: 115-196 (p/(cm^2-sec-ster-MeV); 310-580 (p/(cm^2-sec-ster-MeV); 1060-1900 (p/(cm^2-sec-ster-MeV).
The analysis of the data showed that between 11 and 17 March 2022 the Earth was reached by a dense proton flux which produced some geomagnetic perturbations of G1 and G2 degree (**Fig. 2**).

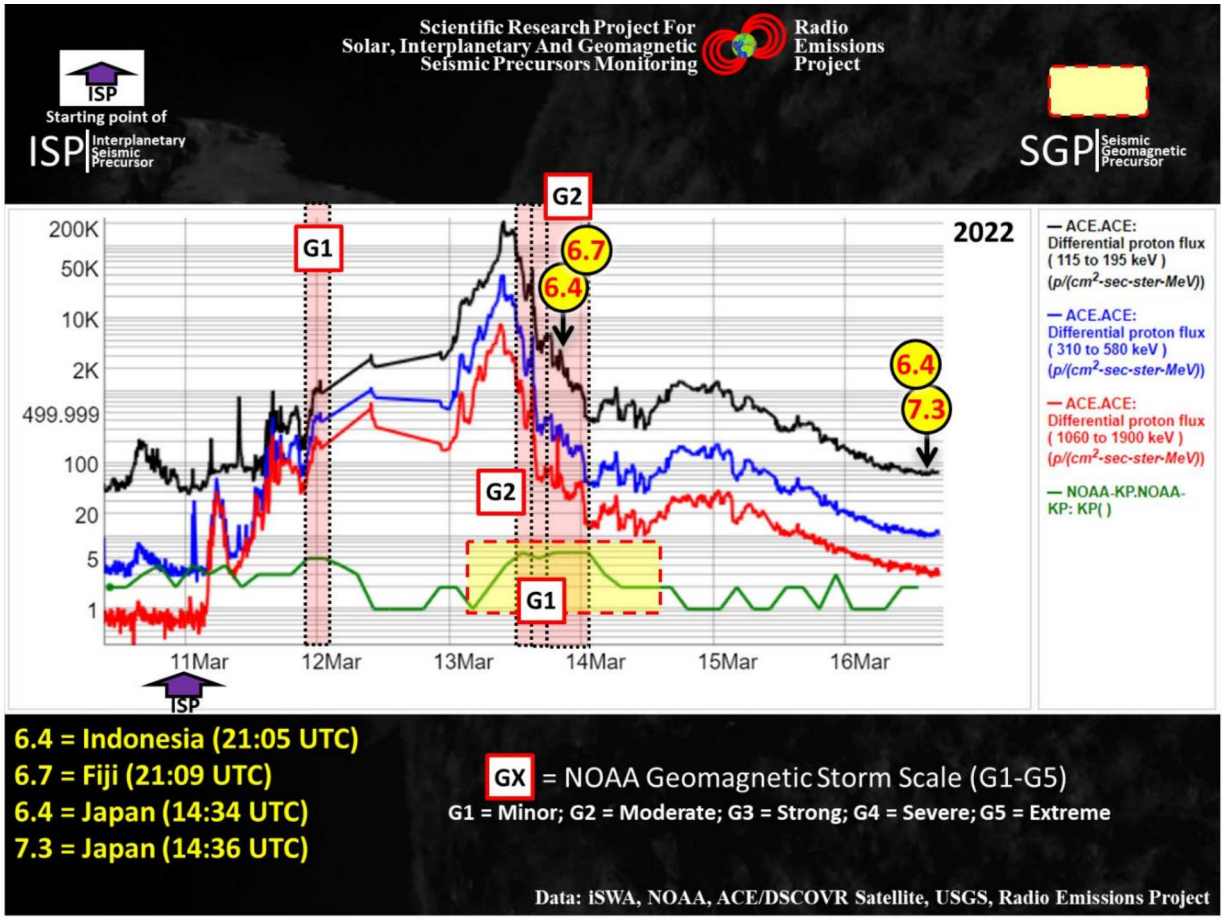

Fig. 2 – Solar ion flux and Kp index modulation in relation to the global seismic activity M6+ recorded between 13 and 16 March. *Graph contains the data on the solar wind proton density variation recorded between 10 and 16 March 2022 at the L1 Lagrange point by Advanced Composition Explorer (ACE) satellite; the variation of Kp-Index and the temporal markers (black vertical arrows) of M6+ earthquakes recorded in the same period. The vertical purple arrow represents the beginning of the "gradual" proton density increase (beginning of Interplanetary Seismic Precursor). The yellow areas surrounded by the red dashed line indicates increases of Kp-Index that preceded the M6+ earthquakes (Geomagnetic Seismic Precursor). The data on the proton density variation and the Kp-Index were provided by iSWA. iSWA is a flexible, turn-key, Web-based dissemination system for NASA-relevant space weather information that combines forecasts based on the most advanced space weather models with concurrent space environment information. The data on seismic activity were provided by United States Geological Survey (USGS). Credits: Radio Emissions Project, USGS.*

Analyzing the data provided by Advanced Composition Explorer (ACE) satellite it was possible to understand that the increase began on 11 March 2022, at about 00:00 UTC, reaching its maximum value on 13 March 2022 at about 09:45 UTC. After March 13, 2022, the proton density decreased progressively, undergoing a small increase between March 14 and 15, 2022, and then gradually decreases again to the basal value, reached on March 18 at 14:10 UTC (**Fig. 2**). During this proton increase, four G1-G2 degree geomagnetic storms (NOAA Geomagnetic Storm Scale) were recorded on Earth (**Fig. 2**):

1) G1 = recorded between 11 and 12 March 2022;
2) G2 = recorded on March 13, 2022 at 13:30 UTC;

3) G1 = recorded on March 13, 2022 at 16:30 UTC;
4) G2 = recorded between 13 and 14 March 2022.

A geomagnetic storm occurs following the impact of a very dense solar ion flux on the earth's magnetosphere: a phenomenon that was recorded between 11 and 17 March 2022 (**Fig. 2**). In confirmation of what has been stated up to now, it is possible to observe the **Fig. 3**:

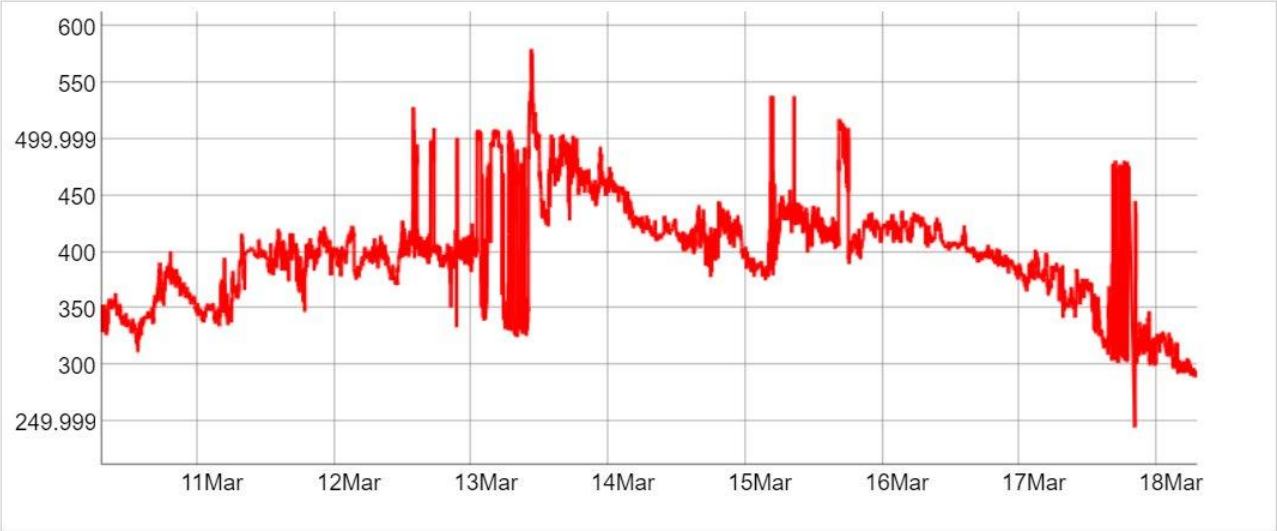

Fig. 3 – Solar wind bulk speed recorded between 11 and 18 March 2022. *The graph above shows the speed of the solar wind recorded between 11 and 18 March 2022 by the DSCOVR Satellite, located in the Lagrangian orbit L1. Credits: iSWA.*

The **Fig. 3** shows the trend of the solar wind speed between 11 and 17 March 2022: the maximum speed (580.1 km/s) was recorded on 13 January 2022 at 10:47 UTC, i.e. about 1 hour later than the maximum proton increment recorded on January 13, 2022 at 09:45 UTC: it is a series of data that confirm the moderate extent of the impact between the solar ion flux and the Earth's magnetosphere. Since the perturbations of the Earth's geomagnetic field and, more generally, the increases in the solar proton flux are accompanied by a resumption of potentially destructive seismic activity that is recorded on a global scale, the authors analyzed the temporal data of potentially destructive earthquakes recorded between 13 and 16 March 2022 to understand if these were related to the variation curves. The result of the correlation study confirmed that the four M6+ seismic events were recorded after the start of the solar proton increase and after some geomagnetic storms (**Fig. 2**). What has been ascertained confirms what the authors have observed from 2011 to today: the potentially destructive seismic activity is closely related to solar activity and, more specifically, to the increases in the solar proton flux that are able to trigger geomagnetic perturbations or simple increases of the Kp-index. But that is not all. The modulation of the seismic events that occurred between 13 and 16 March 2022 confirms the average distribution with respect to the variation curve, observed by the authors between 1 January 2012 and 31 December 2021 (**Fig. 4**): 50.15% of potentially destructive seismic events occur after the maximum increase in the density of the solar proton flux, ie during the bending phase of the proton density (phase "C") and the four potentially destructive seismic events recorded between 13 and 16 March 2022 were recorded just after the maximum increase recorded on March 13, 2022 (**Fig. 2**).
The distribution (in percentage) of the potentially destructive seismic events visible in **Fig. 4** always maintains the same ratio (with small variations) even analyzing the data of each year individually. This indicates that the distribution of potentially destructive seismic events that occur on a global scale follows rules based on solar activity; rules that, unfortunately, the authors have not been able to clarify at the moment but on which it is possible to make hypotheses [19] [21] [36] [37]. It is not known to the authors why the majority of potentially destructive earthquakes (M6+) that occur on a global scale are mainly distributed on phase A (increase) and phase C (decrease) but it can be agreed that these two phases represent the moments in which the solar wind proton density variation does not remain stable but tends to vary quickly.
Since through the studies carried out by the authors it has been proven that all potentially destructive seismic events that occur on a global scale are always preceded by an increase in the solar proton flux, from September 2020 the authors began to measure the rate of change (increase) of the solar proton flux density starting from the basal value that precedes any potentially destructive seismic event.

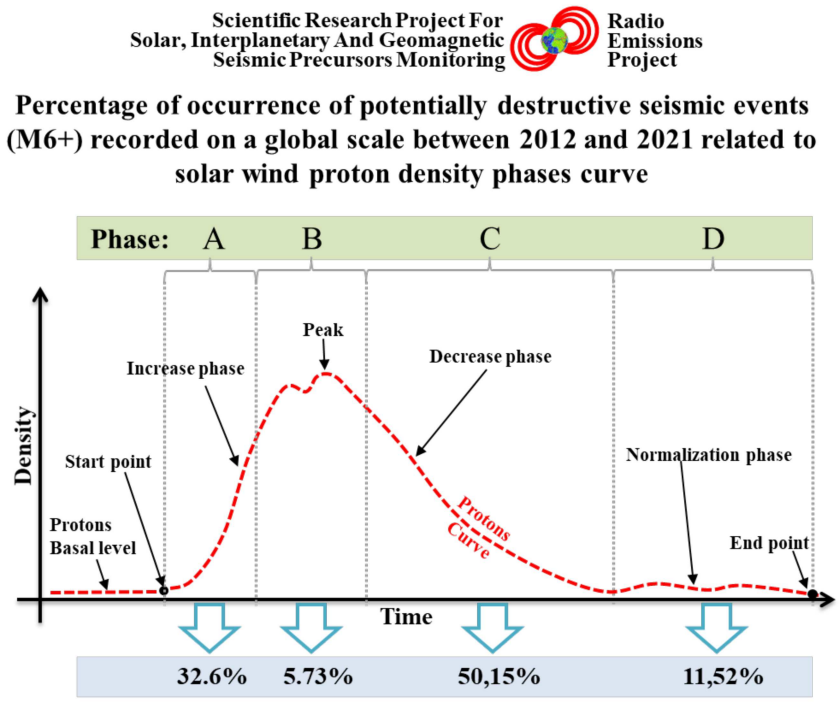

Fig. 4 – Distribution of potentially destructive seismic events (M6+) recorded on a global scale with respect to the proton variation curve*. In the graph above the typical proton curve of a "gradual" type event has been reproduced. In the graph above it is possible to observe the distribution (in percentage) of all potentially destructive seismic events recorded on a global scale from 1 January 2012 to 31 December 2021, compared to the density value of the solar proton flux recorded at the same instant in the Lagrangian point L1. Credit: Radio Emissions Project, iSWA, USGS.*

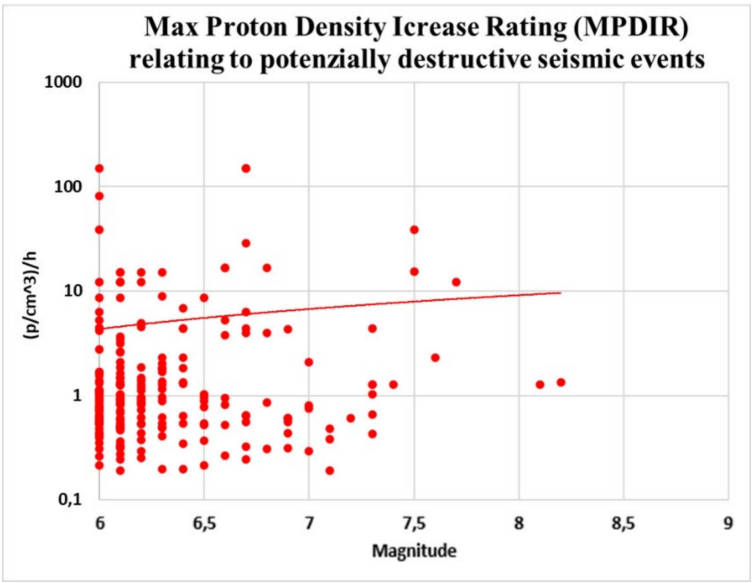

Fig. 5 – Max Proton Density Increase Rating (MPDIR)*. The graph above shows the maximum rate of increase reached by the density of the solar proton flux in the period preceding the seismic event associated with the proton increase. Credit: Radio Emissions Project.*

The unit of measurement that the authors used is (p/cm^3)/h and represents the maximum rate of increase measured between the basal value that preceded the M6+ seismic event and the maximum value reached within the time interval in the which earthquake was recorded (sometimes the maximum increase coincides with the time marker of the seismic event). The preliminary results of this study were obtained by analyzing the data on the solar proton flux that preceded 216 M6+ seismic events recorded between September 2020 and March 2022: these showed that the rate of change increases with the increase in the magnitude of the earthquake (**Fig.**

5). This result, if compared with the data obtained on the time intervals recorded between the beginning of the increase in the density of the solar proton flux (basal level that preceded a specific potentially destructive seismic event) and the seismic event associated with the proton increase itself (on average each proton increase is associated with 2.87 seismic events; January 1, 2012 - March 31, 2022) (**Fig. 4**) can support the hypothesis of the existence of a form of electromagnetic interaction responsible for the alteration of the static equilibrium of the faults, as hypothesized by the authors in some previous works [19] [21] [36] [37].
From the beginning of the proton increase recorded on March 11, 2022, at about 00:00 UTC, to the four M6+ seismic events recorded between 13 and 16 March 2022, have passed:

a) M6.4 Philippines earthquake = 17.5 hours;
b) M6.7 Indonesia earthquake = 17.5 hours;
c) M6.0 Japan earthquake = 83 hours;
d) M7.3 Japan earthquake = 83 hours.

By analyzing the distribution of all time intervals related to the M6+ seismic activity recorded between 2012 and March 2022, it appears that the average time interval is approximately 103.07 hours, equivalent to 4.29 days. In the case of the four potentially destructive seismic events recorded between 13 and 16 March 2022, it is clear that by analyzing the modulation of the solar wind it was possible to understand when the proton increase began (start point of Interplanetary Seismic Precursor); from the moment that the start point of the proton increment was identified, the authors expected a resumption of M6+ global seismic activity; recovery which takes place on average within 103.07 hours. In the specific case, the first two seismic events (Philippines and Indonesia earthquakes) were recorded after 17.5 hours from the start of the proton increase. Since, as has been said, potentially destructive seismic activity is always preceded by a proton increase, the analysis of the modulation of the solar ion flux density could be considered a convenient method to understand, on a global scale, when a recovery of M6+ seismic activity is expected.

Conclusions

In conclusion, we can say that the potentially destructive seismic activity recorded on a global scale between 13 and 16 March 2022 is closely related to solar activity. This is a type of correlation observed by the authors for the first time in 2011 and analyzed in more detail starting from 2012. [1]. The detailed analysis of solar activity allowed us to establish that the four M6+ seismic events recorded between 13 and 16 March 2022 were preceded by an increase in the density of the solar proton flux which produced some low-moderate geomagnetic storms. which also preceded the four potentially destructive seismic events. The distribution of the time intervals recorded between the start of the proton increase and the seismic events recorded between 13 and 16 March 2022 follows the same distribution observed for potentially destructive seismic events recorded on a global scale between 1 January 2012 and March 2022.
The authors propose the use of detailed analysis of the proton density modulation of solar ion flux as a convenient method for understanding when a resumption of potentially destructive seismic activity is expected on Earth.

Credits

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