Space weather and geomagnetic activity related to M6+ earthquakes recorded between 12 and 15 April 2012

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Abstract

Between 11 and 15 April 2012, ten strong seismic events were recorded on our planet, including the seismic train that occurred in Northern Sumatra whose main shock (M8.6; April 11, 2012) was not only the most highest ever recorded in a transform fault, but achieved two other records: the strongest within a plate (previously it was thought that such strong earthquakes could only occur at the edge of subducting or colliding plates) and the most strong in a lateral slip fault. The authors analyzing the modulation of the solar activity verified that the ten seismic events were preceded by a solar wind proton density increase which produced a series of increases in the Earth's geomagnetic activity.

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

Introduction

2012 will be remembered as the year in which two M8+ earthquakes were recorded in Northern Sumatra within a few hours (April 11, 2012) of each other and in total ten M6+ seismic events recorded between 11 and 15 April 2012 (**Fig. 1**):

1) Northern Sumatra M8.6 earthquake, recorded on April 11, 2012 at 08:38:36 UTC (20km depth);
2) North Indian Ocean M6.0 earthquake, recorded on April 11, 2012 at 09:27:56 UTC (10km depth);
3) Northern Sumatra M8.2 earthquake, recorded on April 11, 2012 at 10:43:10 UTC (25,1km depth);
4) Oregon M6.0 earthquake, recorded on April 11, 2012 at 22:41:46 UTC (8km depth);
5) Mexico M6.5 earthquake, recorded on April 11, 2012 at 22:55:10 UTC (20km depth);
6) Mexico M6.0 earthquake, recorded on April 12, 2012 at 07:06:00 UTC (9km depth);
7) Mexico M7.0 earthquake, recorded on April 12, 2012 at 07:15:48 UTC (13km depth);
8) Drake Passage M6.2 earthquake, recorded on April 14, 2012 at 10:56:19 UTC (15km depth);
9) Vanuatu M6.2 earthquake, recorded on April 14, 2012 at 22:05:26 UTC (11km depth);
10) Northern Sumatra M6.2 earthquake, recorded on April 15, 2012 at 05:57:40 UTC (25km depth).

The peculiarity of this seismic train was that it occurred during an impressive increase in the density (p/(cm^2-sec-ster-MeV)) of the solar ion flux (Interplanetary Seismic Precursor or ISP) and in particular of the solar proton flux that affected the following energy fractions:

- 310-580 KeV;
- 761-1220 KeV;
- 1060-1900 KeV.

This type of correlation is not new, in fact the authors observed this phenomenon for the first time in 2011 [3-16] [18-25] and from 1 January 2012 to date they are engaged in a vast correlation study that has allowed them to establish for the first time ever (since the end of 2012 [1]) that all potentially destructive seismic activity (M6+) that is recorded on a global scale is always preceded by a solar wind proton density increase. To confirm what has just been stated, the ten seismic events considered in this work were preceded by an increase in the density of the solar ion flux (**Fig. 2**)

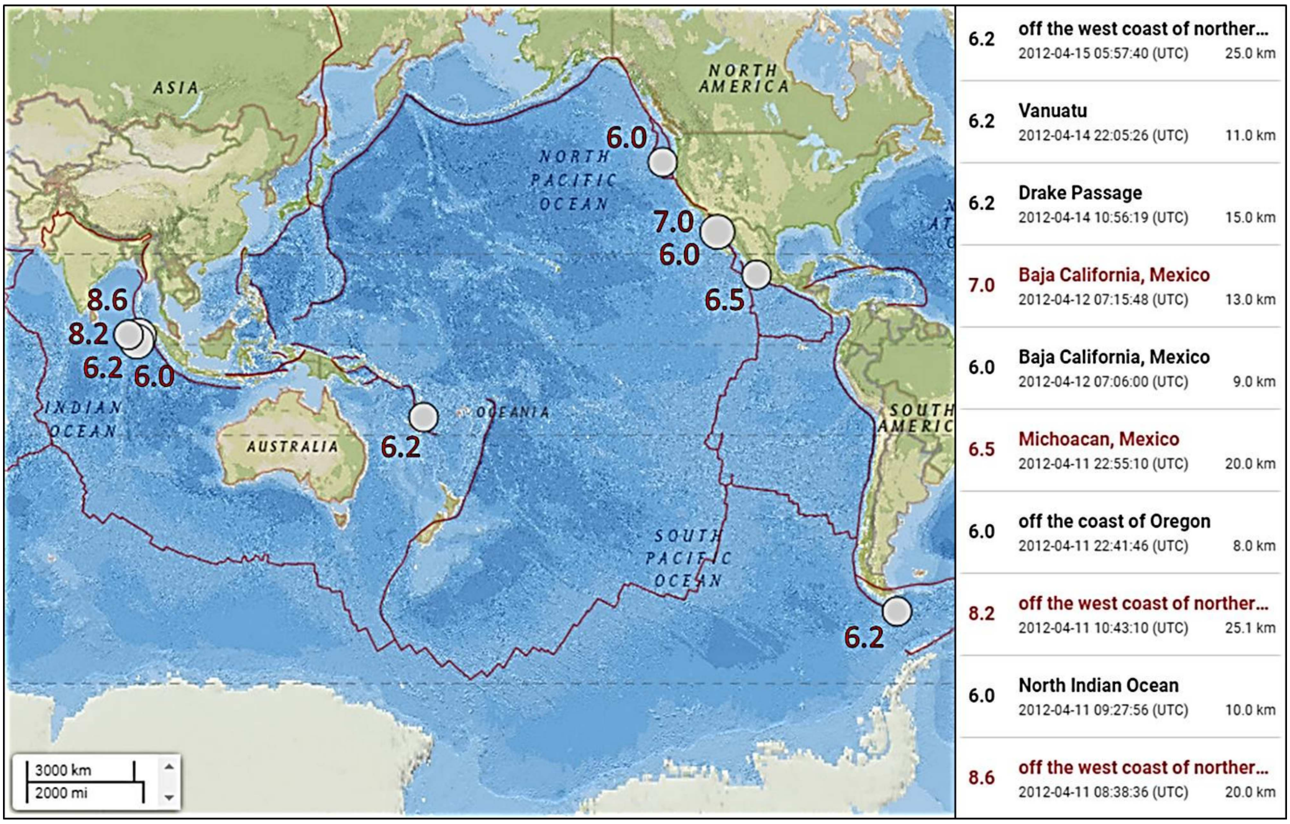

Fig. 1 – Seismic epicenter of M6+ earthquakes recorded between 11 and 15 April 2012. The map above shows the seismic epicenter of ten M6+ earthquakes recorded between 11 and 15 April 2012.
Credits: USGS, Radio Emissions Project.

Data analysis

The Advanced Composition Explorer (ACE) satellite (located in Lagrangian point L1) between 13:30 UTC on April 9, 2012 and April 15, 2012 detected a massive solar wind proton density increase which reached its maximum value on 9 April 2012 at 09:15 UTC, then progressively decreases until reaching the basal level on April 16, 2012 (**Fig. 2**). This type of proton increase is classified as a "gradual" increase as it occurs in a non-impulsive way and lasts on average a few days.
After this main increase, the ACE satellite recorded a second (but more timid) increase that overlapped the main one: the latter manifested itself instrumentally on April 12, 2012 at 17:00 UTC and ended on April 13, 2012 at 11:25 UTC, reaching its maximum value on April 13, 2012 between 00:30 UTC and 04:40 UTC: precisely during this time interval a proton increase of "impulsive" type was recorded which reached a density of almost 19000 p/cm^2-sec-ster-MeV between 1060 and 1900 KeV, and 365 p/cm^2-sec-ster-MeV between 761 and 1220 KeV (**Fig. 2**). This impulsive proton increase was initially superimposed on a geomagnetic storm of class G1 (NOAA G Scale) (**Fig. 2**) which occurred on April 13, 2012 between 01:30 UTC and 04:30 UTC (**Fig. 3**). Geomagnetic storms of this type are the direct consequence of the solar ion flux that interacts with the Earth's magnetosphere when it assumes higher density and velocity values than the basal ones. This interaction phenomenon is known by the term "coupling".

Observing **Fig. 2** it is possible to note that the seismic train represented by the ten potentially destructive earthquakes recorded between 11 and 15 April 2012 were preceded by the proton increment of gradual and impulsive type recorded between 9 and 16 April 2012. More exactly the first seven seismic events:

1) Northern Sumatra M8.6 earthquake, recorded on April 11, 2012 at 08:38:36 UTC (20km depth);
2) North Indian Ocean M6.0 earthquake, recorded on April 11, 2012 at 09:27:56 UTC (10km depth);
3) Northern Sumatra M8.2 earthquake, recorded on April 11, 2012 at 10:43:10 UTC (25,1km depth);
4) Oregon M6.0 earthquake, recorded on April 11, 2012 at 22:41:46 UTC (8km depth);
5) Mexico M6.5 earthquake, recorded on April 11, 2012 at 22:55:10 UTC (20km depth);

6) Mexico M6.0 earthquake, recorded on April 12, 2012 at 07:06:00 UTC (9km depth);
7) Mexico M7.0 earthquake, recorded on April 12, 2012 at 07:15:48 UTC (13km depth);

were recorded after the gradual proton increase, while the last three seismic events:

8) Drake Passage M6.2 earthquake, recorded on April 14, 2012 at 10:56:19 UTC (15km depth);
9) Vanuatu M6.2 earthquake, recorded on April 14, 2012 at 22:05:26 UTC (11km depth);
10) Northern Sumatra M6.2 earthquake, recorded on April 15, 2012 at 05:57:40 UTC (25km depth);

were recorded after the impulsive proton increase (exactly during the "normalization" phase of the solar proton flow) and after the geomagnetic storm of class G1.

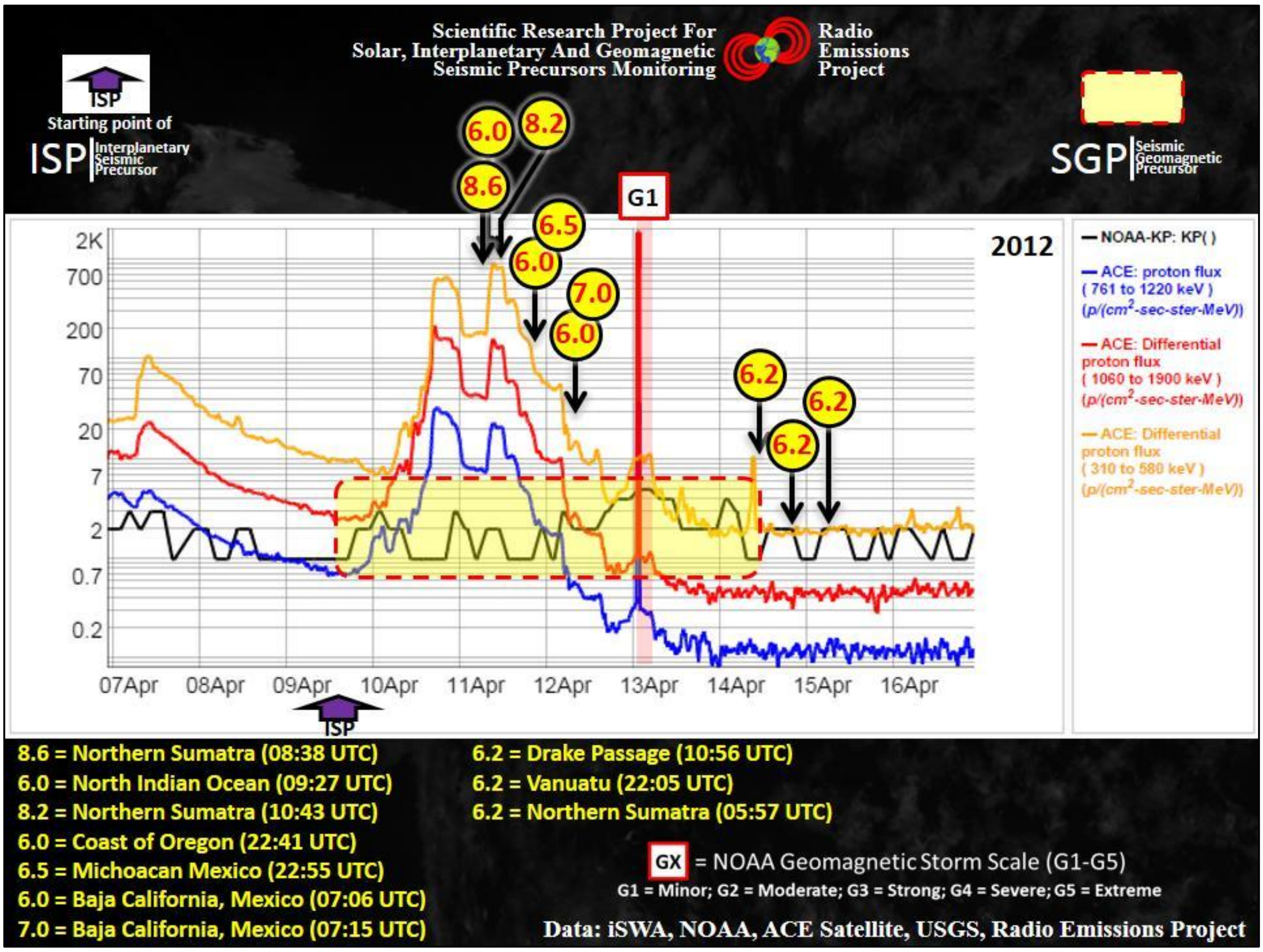

Fig. 2 – Variation in solar ion flux and Earth's geomagnetic activity related to the M6+ global seismic activity recorded between 11 and 15 April 2012. Graph contains the data on the variation of solar wind proton density (blu, red and yellow lines) recorded between 7 and 16 April 2012 recorded at the 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 (black line) 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: iSWA, USGS, Radio Emissions Project.

It is evident that the variation of the solar ion flux and the variation of the Earth's geomagnetic field represent two different types of seismic precursors of the electromagnetic type which, however, have a common origin: the Sun, solar activity. Since the entity of the geomagnetic perturbation essentially depends on the entity of the density of the solar ion flux and its velocity, it is clear that the potentially destructive seismic activity is not always correlated to geomagnetic storms of class G1-G5: usually the increases of the geomagnetic field correlated to the M6+ global seismic activity are more modest. In fact, we can observe that the main geomagnetic increase started on April 12, 2012 at 04:30 UTC and ended on April 14, 2012 at 06:00 UTC approximately (Fig. 3) and therefore also the sixth and seventh seismic event (Mexico M6.0 earthquake, recorded on April 12, 2012 at 07:06:00 UTC; Mexico M7.0 earthquake, recorded on April 12, 2012 at 07:15:48 UTC) were recorded during the initial phase of a geomagnetic perturbation that then it reached the G1 class.

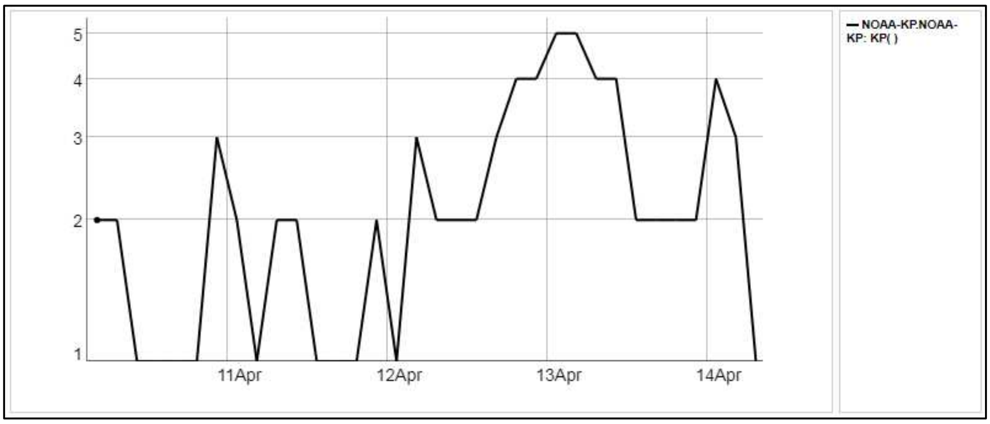

Fig. 3 – Kp Index related to M6+ global seismic activity recorded between 11 and 15 April 2012. The graph shows the trend of the Kp Index recorded between 10 and 14 April 2012. Credits: iSWA, Radio Emissions Project.

Another interesting fact that the authors want to highlight concerns the synchronism of the ten seismic events with respect to their geographical position. Analyzing the schedules of the seismic train it is possible to highlight that the epicenters were recorded according to a rotation that proceeds clockwise (**Fig. 4**).

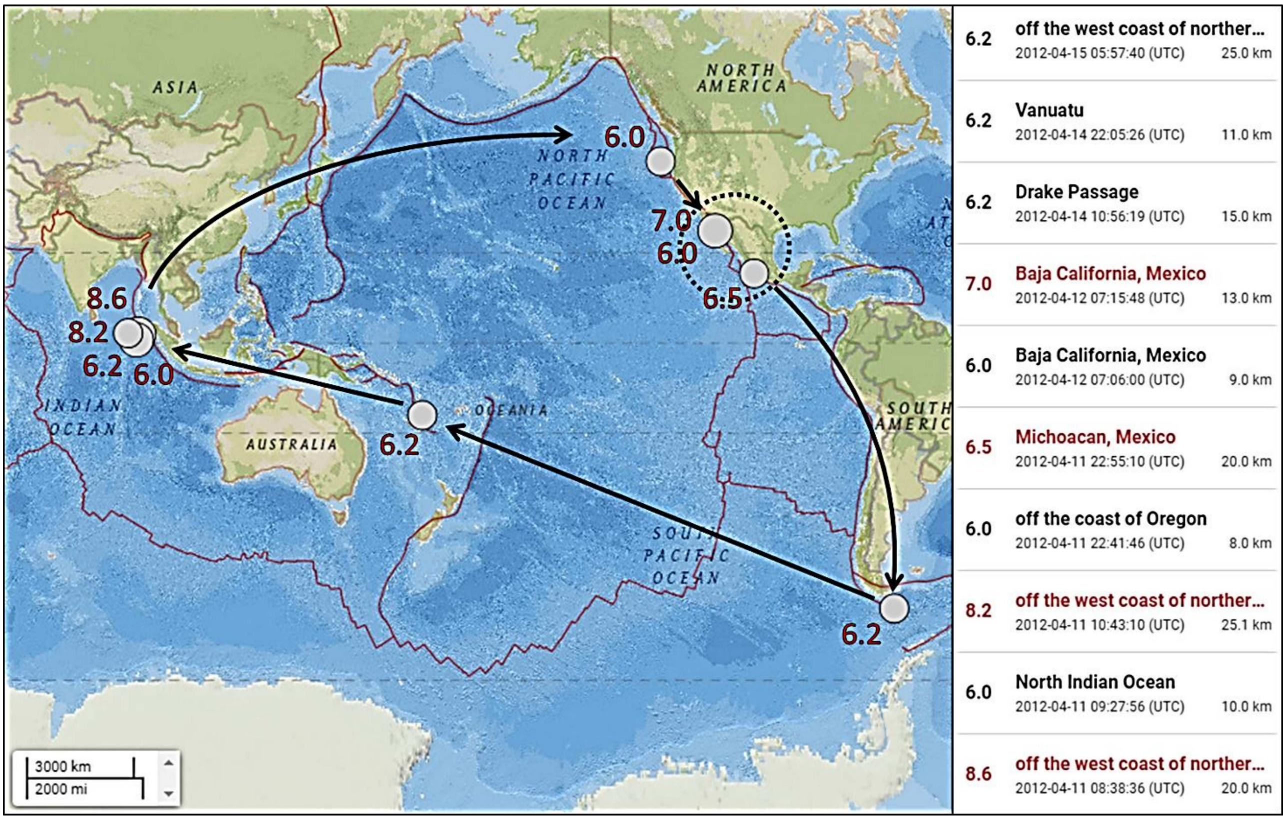

Fig. 4 – Hourly rotation of the M6+ seismic epicenters recorded between 11 and 15 April 2012. The graph above shows the temporal rotation of the M6+ seismic epicenters recorded between 11 and 15 April 2012. Credits: iSWA, Radio Emissions Project.

The seismic activity initially started in the Sumatra area then moved to the Oregon coast, and then it affected Mexico, then the Drake Passage, the Vanuatu seismic area and then ended where it started: North of Sumatra.

Currently there is no scientific explanation that can explain why the M6+ seismic train recorded between 11 and 15 April 2012 occurred with this type of synchrony, but we know that all seismic events are related to an intense increase in solar ion flux. (Interplanetary Seismic Precursor) which produced a vast geomagnetic perturbation (Seismic Geomagnetic Precursor). Further studies are needed.

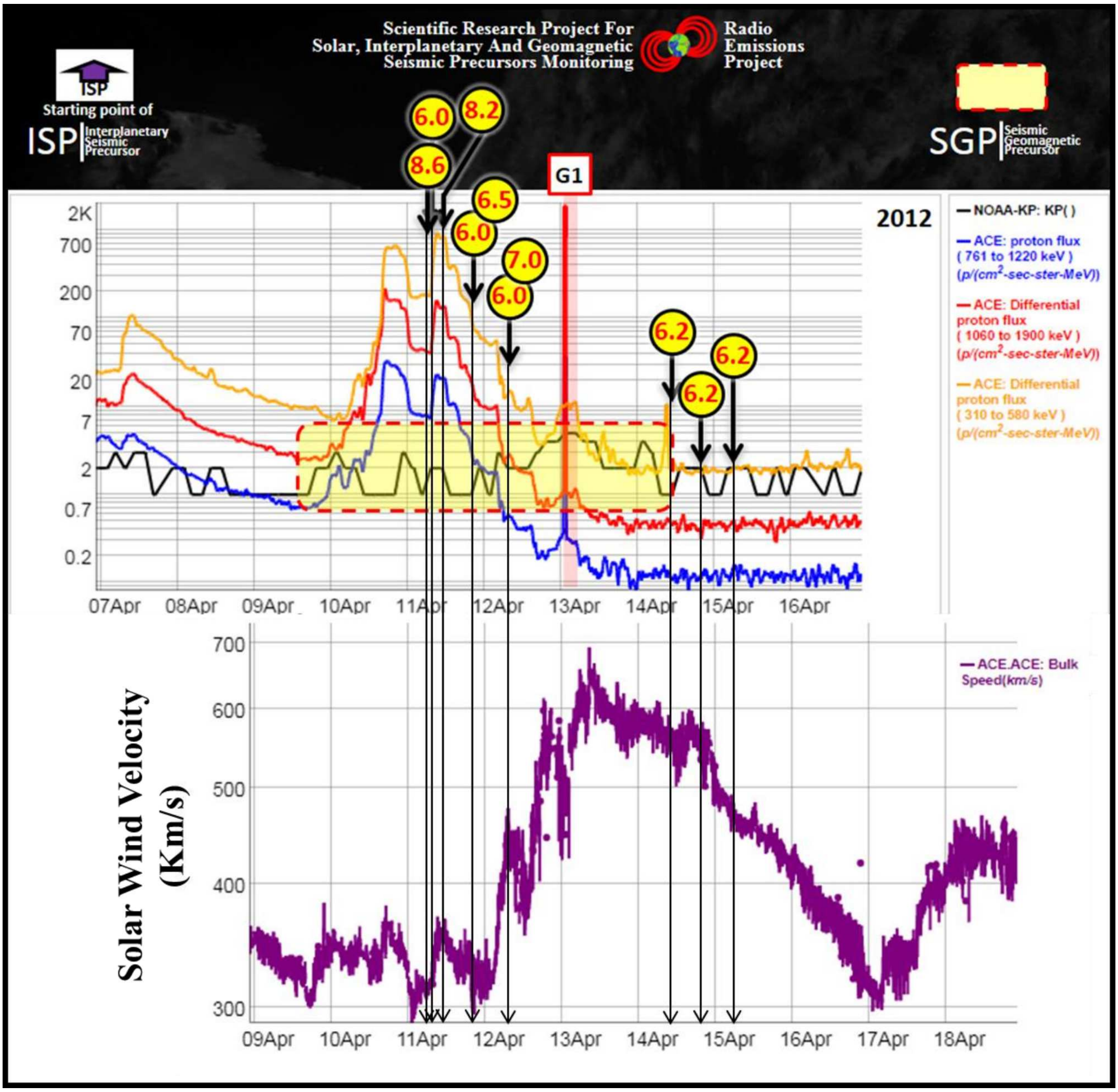

Fig. 5 – Solar wind velocity related to the M6 + seismic train recorded between 11 and 15 April 2012. The graph above shows the variation of the solar wind speed recorded at the L1 Lagrange point by Advanced Composition Explorer (ACE) satellite between 9 and 18 April 2012: the data was superimposed on the data relating to of solar wind proton density increase by discussed in the previous pages. Credits: iSWA, Radio Emissions Project.

Fig. 5 shows, instead, the variation curve of the solar ionic flow velocity which took place between 9 and 18 April 2012. By analyzing the curve, it is possible to verify that the geomagnetic storm of class G1 was sustained by a rapid increase in velocity of the solar wind: a "foregone" fact that can generally be associated with geomagnetic perturbations of class G1-G5. Through **Fig. 5** it is possible to understand the importance of a wide-field study carried out in the field of scientific research dedicated to seismic prediction: considering the data relating to the speed of the solar wind and those relating to the density of the solar ion flux it is possible have a more complete and clear picture of the close correlation that exists between potentially destructive seismic activity and solar activity. The seismic train started after a rapid and important increase of solar wind proton density increase which was followed by a reduction in the density of this flux but which underwent a rapid increase in its speed: two sides of the same coin that have the ability to perturb the Earth's geomagnetic field.

Conclusions

The monitoring of solar activity and geomagnetic activity has proved to be an effective method for predicting (with an average warning of 108 hours) the resumption of M6+ global seismic activity [1-25]. The authors understood the enormous predictive potential of solar activity monitoring between 2010 and 2011 after a preliminary analysis of the variation of Interplanetary Magnetic Field (IMF) which revealed that many potentially destructive seismic events were recorded after or during perturbations of IMF; the next step was to analyze in detail all the parameters of the solar wind to identify one or more phenomena of an electromagnetic nature (of solar origin) related to the M6+ global seismic activity. The study began on January 1, 2012. At the end of 2012 the authors were able to understand that all M6+ seismic events recorded on a global scale were always preceded by solar wind proton density increase [1]. From 2012 to today this trend has always been confirmed.
The study presented in this work is only a small part of the evidence that the authors have collected during their career on the effectiveness of this seismic forecasting method that the same authors have implemented (and proposed several times) to predict when (and not where) a resumption of M6+ seismic activity on a global scale is expected. Today, thanks to this method, it is possible to know when a resumption of potentially destructive seismic activity is expected on a global scale. The difficulty of the method consists in identifying the exact moment (beginning of Interplanetary Seismic Precursor) in which the density of the solar proton flux begins to increase: to achieve this result it is necessary to have data on the variation of solar wind proton density increase updated almost in real time. These data are provided by artificial satellites in Lagrangian orbit L1 launched into orbit certainly not to carry out studies on seismic prediction, therefore we would need an artificial satellite expressly dedicated to studies conducted on the correlation between solar activity and seismic activity capable of providing data with a frequency of a few seconds. Another phenomenon that seems to have a close relationship with the potentially destructive seismic activity is represented by the variations or perturbations of the Earth's geomagnetic field (Seismic Geomagnetic Precursors). These are the direct expression of the impact that the dense and/or fast solar ion flux has on the terrestrial magnetosphere and, therefore, it is obvious that if the M6+ seismic activity is correlated to the variations of solar wind proton density increases it is evident that the the same M6+ seismic activity is also correlated to the variation of the geomagnetic field. Thanks to the data collected in the last 9 years by the authors we know that a series of electromagnetic phenomena of solar origin and of a geomagnetic nature are closely related to the potentially destructive seismic activity [1-25] but we are not yet able to explain the seismogenic mechanism and to understand the geographical area where the strong earthquake will strike. Since 2017 the authors have developed and are experimenting an innovative method that allows to make crustal diagnosis by analyzing the background radiofrequency through an electromagnetic monitoring network installed mainly in Central Italy which is partly multiparametric. This new method allowed the authors to identify low or medium-low magnitude seismic epicenters with a few days' notice [26-40]. It is the authors' opinion that all this will represent the future of forecasting great earthquakes and more.

Credits

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