Solar activity correlated to the M7.0 Japan earthquake occurred on April 15, 2016

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Abstract: The authors of this study wanted to verify a possible relationship between the M7.0 earthquake, which occurred near Kumamoto, Kyushu, Japan on April 15, 2016 at 16:25:06 UTC and the solar activity. The authors have scientifically demonstrated that there is a relationship between M6+ global seismic activity and solar activity and have had occasions to explain that large earthquakes, that can also generate tsunami, are always preceded by a variation of the interplanetary medium ion density; this variation has been defined by the authors as a "Interplanetary Seismic Precursor" (ISP) because, as already mentioned, it always precedes the strong earthquakes. The Interplanetary seismic precursors are phenomena that originate from the Sun through what the authors defined as "Solar Seismic Precursors" (SSP) and which are represented by: Coronal mass ejection (CME), coronal holes, solar flares and magnetic loops placed above the sunspots. The authors were able to confirm that from 2012 to today, all M6+ earthquakes that occur on our planet are always preceded by this type of event and, therefore, the authors had expected that the Japanese M7.0 earthquake was preceded by an ionic change in the solar wind.

***Keywords**: Coronal mass ejection, solar seismic precursors, earthquake prediction, interplanetary seismic precursor, solar wind.*

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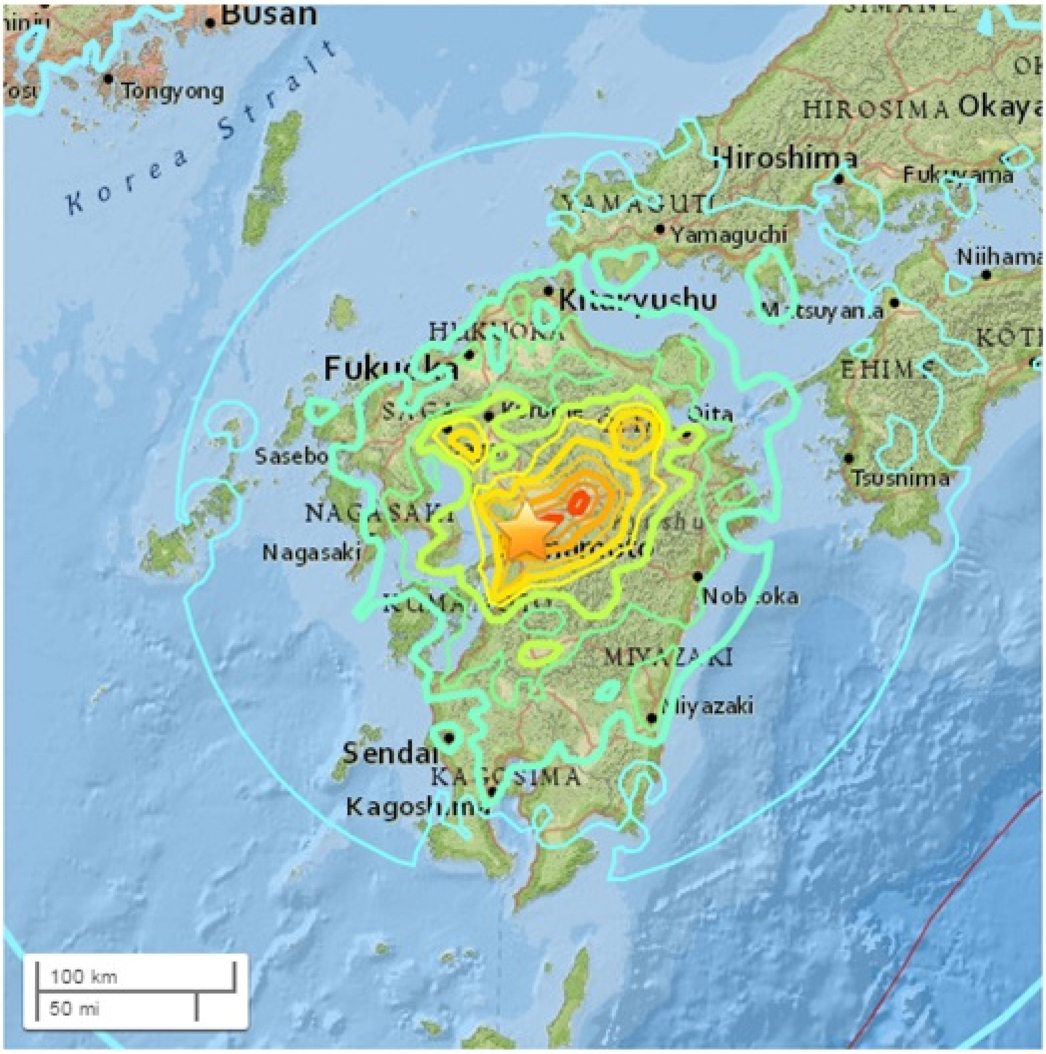
INTRODUCTION

There are many data suggesting a potential relationship between the potentially destructive earthquakes on a global scale and solar activity (Straser et al., 2014-2015). Therefore, it is imperative to understand how this happens. The explanations that the scientific community has proposed from the 1970 to today have been numerous but what has been definitively understood is that the variations of the ion density of the interplanetary medium are the only physical phenomenon to have the highest specificity in the context of seismic prediction (Anagnostopoulos et al., 2010; Odintsov et al., 2006; Makarova and Shirochkov, 1999; Simpson, 1968; Nikouravan et al., 2012; Afraimovich and Astafyeva, 2008; Rabeh et al., 2014). Since 2011 the authors have started tracking the chemical and physical parameters of the solar wind near Earth (interplanetary magnetic field modulation; ion energy and concentration; polarity, speed, temperature and direction of the solar wind; dynamic pressure of the solar wind; magnetopause standoff distance) after noting, between 2009 and 2010, that strong earthquakes were preceded by an increase of natural radio emissions (SELF and ELF bands) and to check if these emissions were connected to geomagnetic and solar activities. The analysis of solar activity related to the analysis of natural radio emissions and M6+ global seismic activity allowed the authors to understand that the seismic activity is always preceded by an increase of solar activity, namely: that the strong earthquakes that occur on a global scale are always preceded by an increase of the solar wind ion density near Earth and by associated geomagnetic field disturbances. These conclusions indicate that the physical phenomenon responsible for the coupling between solar activity and seismic activity is a form of electromagnetic interaction that must be investigated in the coming years. According to the authors this is the new scientific approach that must be followed in the future to predict the potentially destructive earthquakes.

In this context, in 2013 the Italian Space Agency (ASI) and the China National Space Administration (CNSA) have signed an agreement for the construction of the CSES (China Seismo-Electromagnetic Satellite). The first satellite dedicated to monitoring electromagnetic field and waves, plasma and particles perturbations of the atmosphere, ionosphere and magnetosphere induced by natural sources and anthropocentric emitters; and to study their correlations with the occurrence of seismic events. This space mission underlines the importance of the studies that the authors have realized since 2010 and what is the future of scientific research on earthquake predictability. The study that was presented in this paper shows that the strong M7.0 Japanese earthquake occurred on April 15, 2016 was preceded by a solar wind proton density increase, began on April 12, 2016 at 14:15 hours UTC (74 hours before the earthquake). The authors constantly monitor the interplanetary medium ionic variation, and knew that the increase began on April 12, 2016, at 14:15 UTC would be followed by an M6+ seismic event and actually this ion increment preceded eight M6+ earthquakes occurred on a global scale, including the Japanese one. The authors chose to present in this work the M7.0 earthquake occurred in Japan on April 15, 2016 **(Fig. 1**) because this earthquake, unlike other earthquakes, occurred precisely during a strong variation of the interplanetary magnetic field (IMF).



32.782°N 130.726°E depth=10.0 km (6.2 mi)

Fig. 1. Index Map. M7.0 earthquake's epicenter occurred on April 15, 2016 at 16:25:06 UTC (credits: USGS, http://earthquake.usgs.gov/earthquakes/eventpage/us20005iis#general). Concentric colored lines represent a measure (colorimetric scales) of the energy dispersion of the earthquake measured in magnitude (Mw).

METHODS AND DATA

To realize this study, the authors analyzed the space weather conditions (near Earth) and the characteristics of the geomagnetic field in the days that preceded the strong earthquake. In particular, the data taken into consideration were: data on the solar activity concern variation in the ionic density of the solar wind detected by the ACE (Advanced Composition Explorer) satellite orbiting the L1 point (Lagrange point) at 1.5 million kilometers from Earth; Solar Wind Density (ENLIL Heliosphere Ecliptic Plane), variations in interplanetary magnetic field or IMF (GOES); X-ray flux (GOES), temporal monitoring of CMEs events or Solar Coronal Mass Ejections (ISWA); monitoring of the coronal holes position on the Sun's surface (NSO/SOLIS-VSM Coronal Hole); Solar Wind Velocity (ENLIL Heliosphere Ecliptic Plane); Electron flux (NOAA/SWPC); Magnetopause Standoff Distance (CCMC/RT). The data on geomagnetic activity used for the study are represented by Kp-Index and were provided by Space Weather Prediction Center (SWPC).

RESULTS

The results of the study have confirmed the hypothesis of the authors: that the Japanese M7.0 earthquake was preceded by an increase of the interplanetary medium ion density (near Earth), and also confirming also what the authors ascertained from the 2012 data. Specifically, the M7.0 earthquake occurred after an increase of the solar wind proton density (**Fig. 2**) started on April 12, 2016 at 14:15 UTC.

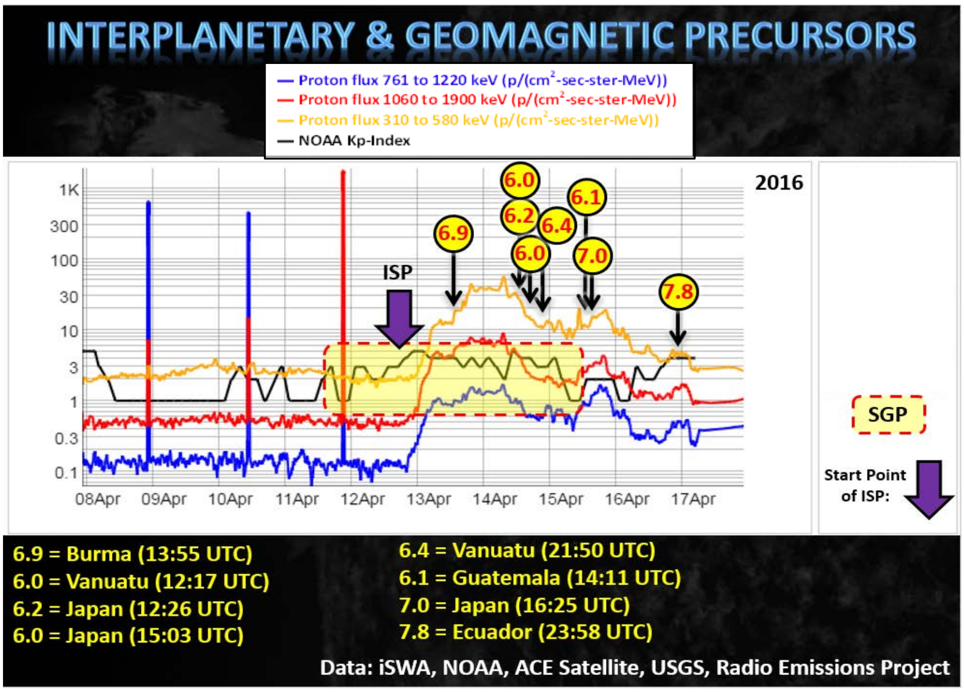


Fig. 2. Solar wind proton density variation. Graph contains the data on the variation of solar wind proton density recorded between 8 and 17 April 2016 at the L1 Lagrange point by Advanced Composition Explorer Satellite; the variation of Kp-Index and the temporal markers (black vertical arrows) of M6+ 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).

DISCUSSION

By analyzing the proton density variation curve and the data on seismic activity provided by the USGS, it has emerged that indeed the M7.0 Japanese earthquake was one of eight seismic events occurred as a result of this proton increase. The energy proton fraction analyzed in this study is comprised between 310 and 1900 keV. Additional confirmation of the close connection between M6+ global seismic activity and solar activity comes from the analysis of the interplanetary magnetic field (IMF) variation (**Fig. 3**). Another important fact connected to the M7.0 Japan earthquake and, in general, connected to all M6+ global seismic activity is the increase of the Earth's geomagnetic field (Cataldi et al., 2013-2015). The increase of geomagnetic activity is thus a direct effect of increased solar activity. If the M7.0 Japan earthquake is truly related to the solar activity, it is clear that this earthquake had to be preceded by an increase of the Earth's geomagnetic field strength. In fact, the instrumental data confirm this thesis and also observations made by the authors from 2012 to today. If one analyzes the trend of the Kp-Index recorded between 9 and 13 April 2016, it becomes clear that the M7.0 Japanese earthquake (and more generally all eight earthquakes registered between 13 and 16 April 2016) was preceded by an increase in the Earth's geomagnetic field that began on April 11, 2016 at 09:00 UTC (**Fig. 4**). This phenomenon has been described by the authors as "Geomagnetic Seismic Precursor" (SGP) and is represented by a geomagnetic disturbance or variation. Analysis of DST and AL Index leaves no doubt in this sense (**Fig. 5**): the M7.0 Japan earthquake was preceded by a weak geomagnetic storm and by an increase of polar magnetic emission. The sequentiality of these seismic precursors (Solar Seismic Precursor, Interplanetary Seismic Precursor and Geomagnetic Seismic Precursor) is a direct evidence of a connection that exists between solar activity and M6+ global seismic activity; evidence that the authors have already had the opportunity to discuss at the international level for some years (Straser et al., 2015; Straser and Cataldi, 2014-2015).

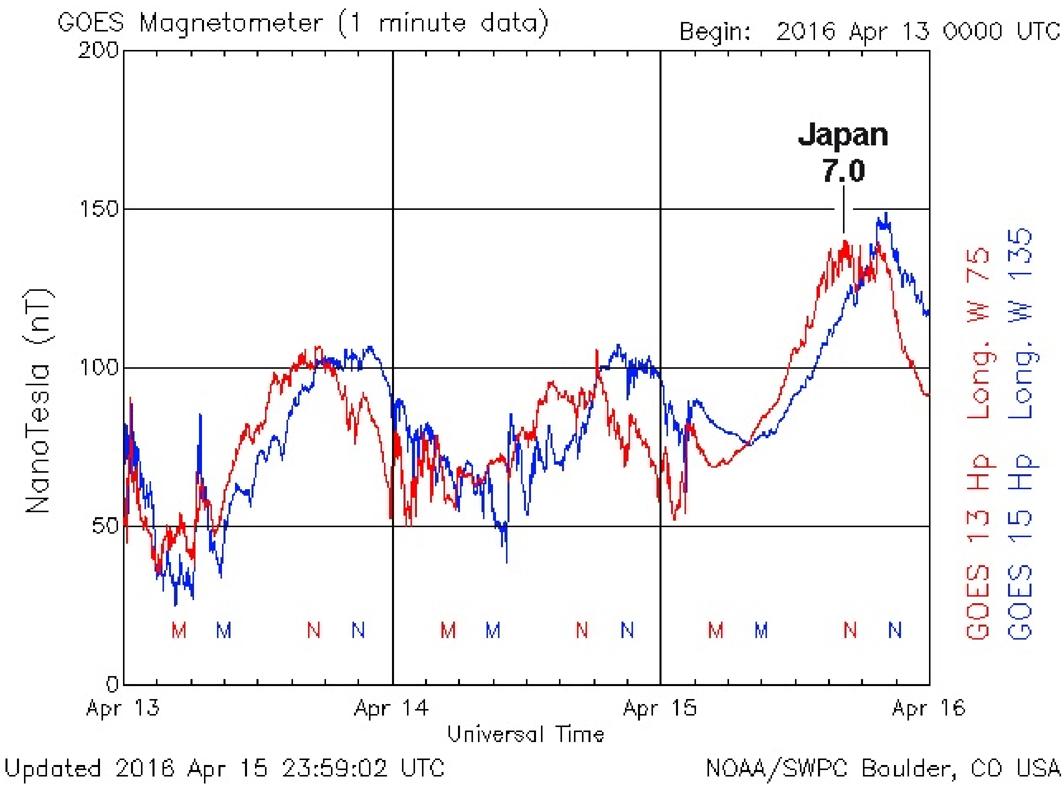


Fig. 3. Interplanetary magnetic field (IMF) variation. The magnetogram contains the data on the interplanetary magnetic field (IMF) variation recorded between 13 and 15 April 2016. The recording was made by two satellites placed in geostationary orbit: GOES 13 and GOES-15. From the graph it is clear that the Japanese M7.0 quake was preceded by an increase in the interplanetary magnetic field (IMF) that started on April 15, 2016 at 06:00 UTC. The main feature of this increase is that has superimposed itself at the time at which it was recorded the M7.0 Japanese earthquake.

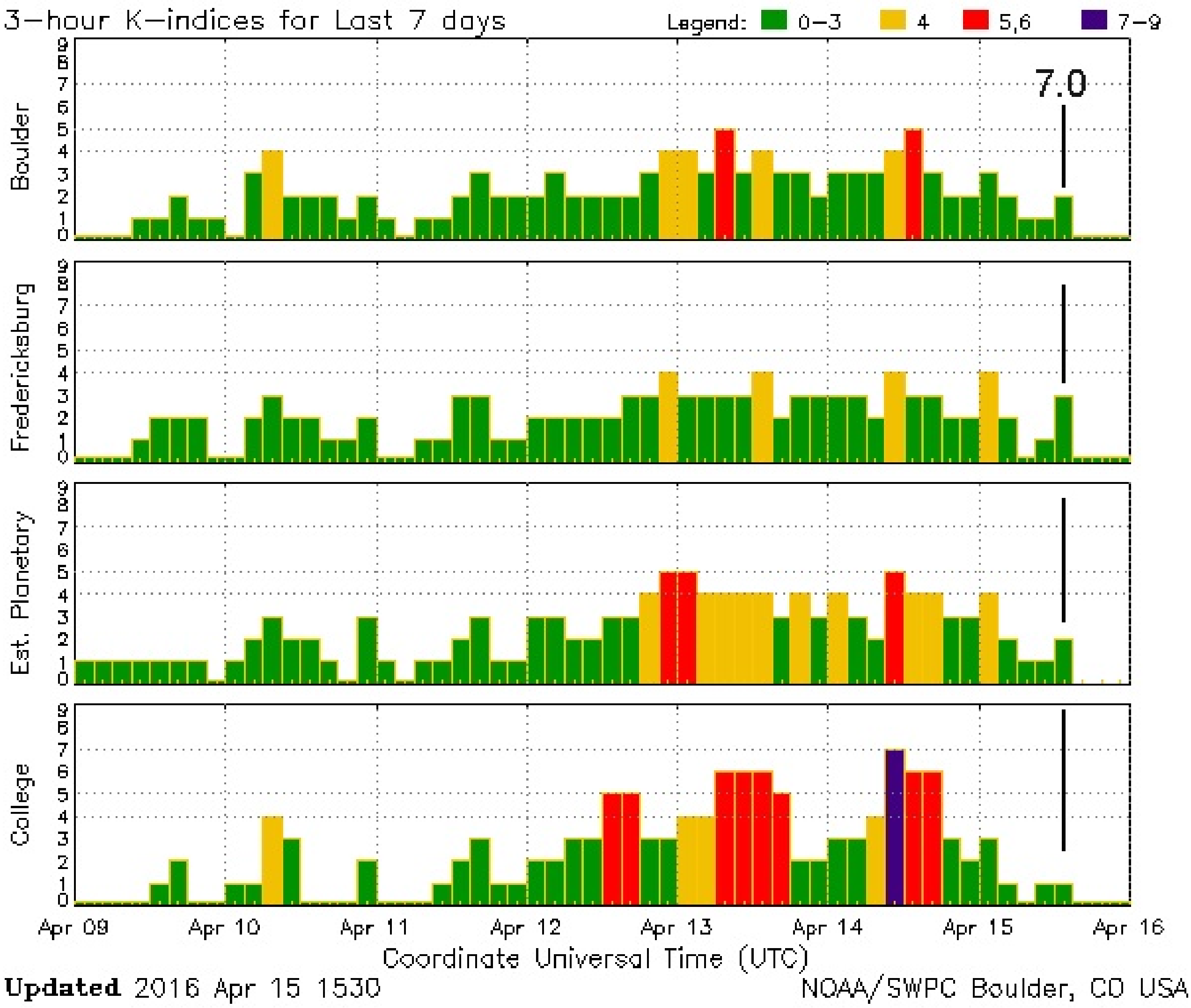


Fig. 4. Kp-Index variation. The graph contains the K-Index (recorded at College, Fredericksburg and Boulder) and Kp-Index data recorded between 9 and 16 April 2016. The Estimated 3-hour Planetary Kp-index is derived at the NOAA Space Weather Prediction Center using data from the following ground-based magnetometers: Sitka, Alaska; Meanook, Canada; Ottawa, Canada; Fredericksburg, Virginia; Hartland, UK; Wingst, Germany; Niemegk, Germany; and Canberra, Australia. The K-index, and by extension the Planetary K-index, are used to characterize the magnitude of geomagnetic storms. Kp is an excellent indicator of disturbances in the Earth's magnetic field and is used by SWPC to decide whether geomagnetic alerts and warnings need to be issued for users who are affected by these disturbances.

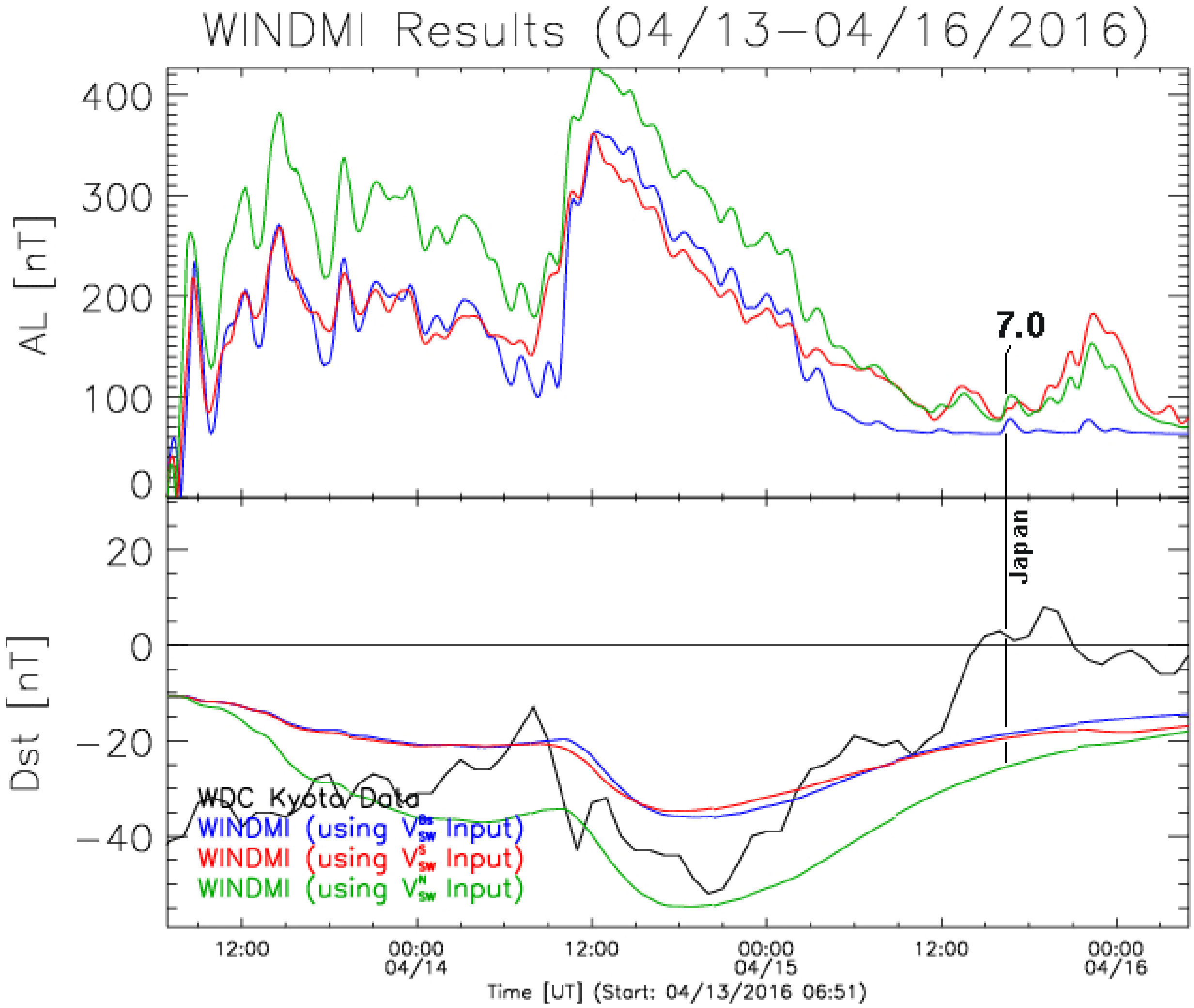


Fig. 5. Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere (WINDMI). The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the Japanese M7.0 earthquake occurred on April 15, 2016. 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 Japanese earthquake occurred on April 15, 2016 was preceded by an increase of solar and geomagnetic activity. Model developed by the Institute for Fusion Studies, Department of Physics, University of Texas at Austin.

CONCLUSION

In conclusion we can confirm that the seismic events of strong intensity (M6+) that occur on a global scale are always preceded by an increase of the proton density of the solar wind. On average, considering the time intervals recorded from January 1, 2012 to April 30, 2016 (604 seismic event, USGS data), 140.9 hours elapse between the beginning of the increase of solar wind proton density increase and the earthquake. The M7.0 Japan earthquake occurred at a time of 74 hours from the start of the proton density increase and at a distance greater than 96 hours from the start of the Kp-Index increase that preceded it. We are convinced that the future of seismic prediction should take space weather, the solar phenomena and the heliophysics as well as the phenomena of geomagnetic nature, into serious consideration.

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