Analysis of possible electromagnetic seismic precursors related to the turkish seismic sequence recorded on february 6, 2023

Valentino Straser[1], Gabriele Cataldi[2], Daniele Cataldi[2-3]

(1) Department of Science and Environment UPKL Brussel (B). valentino.straser@gmail.com
(2) Radio Emissions Project (I). gabrielecataldi5994@gmail.com
(3) Fondazione Permanente G. Giuliani - Onlus (I). daniele77c@hotmail.it

Abstract

On February 6, 2023 a high intensity seismic sequence was recorded in Turkey: M7.8 recorded on February 6, 2023 at 01:17 UTC; M6.7 recorded on February 6, 2023 at 01:28 UTC; M7.5 recorded on February 6, 2023 at 10:24 UTC; M6.0 recorded on February 6, 2023 at 10:26 UTC; M6.0 recorded on February 6, 2023 at 12:02 UTC. The authors analyzed the characteristics of the solar ion flux in the hours and days that preceded this seismic sequence, finding an increase in the density of the solar wind that preceded the Turkish seismic sequence recorded on February 6, 2023. Furthermore, the analysis of the natural electromagnetic background through RDF (Radio Direction Finding) technology allowed the authors to detect pre-seismic radio emissions with an azimuth compatible with the Turkish seismic district.

Keywords: space weather, seismic precursors, proton density, Radio Direction Finding (RDF), Turkey.

Introduction

On 6 February 2023, a high intensity seismic sequence was recorded in Turkey (**Fig. 1**) which caused over 51,000 victims and more than 120,000 wounded (the data refer to 1 March 2023):

- M7.8 earthquake recorded on February 6, 2023 at 01:17 UTC.
- M6.7 earthquake recorded on February 6, 2023 at 01:28 UTC.
- M7.5 earthquake recorded on February 6, 2023 at 10:24 UTC.
- M6.0 earthquake recorded on February 6, 2023 at 10:26 UTC.
- M6.0 earthquake recorded on February 6, 2023 at 12:02 UTC

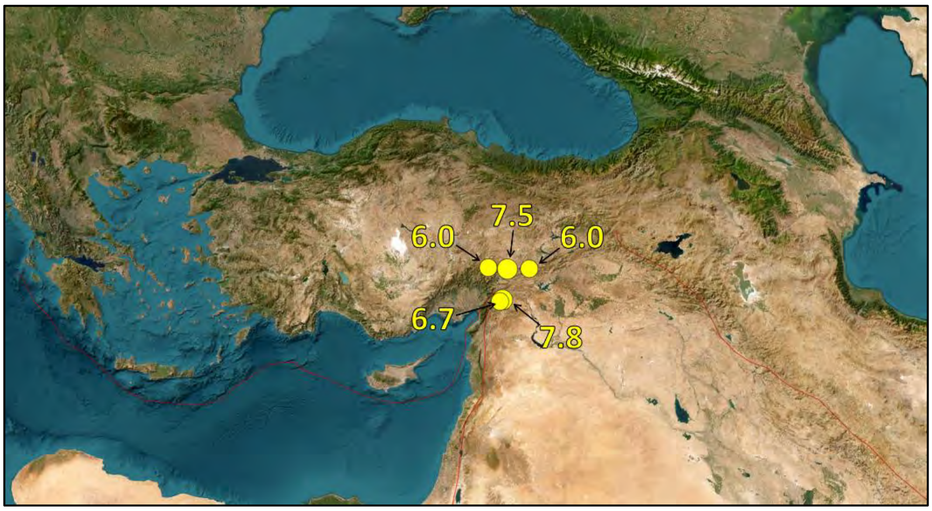

Fig. 1 – Seismic epicenters of the five M6+ seismic events recorded in Turkey on February 6, 2023. *Credits: United States Geological Survey (USGS).*

This seismic sequence is located near a triple junction between the margins of the Anatolian, Arabian and African plates, and involved a segment about 190km long and about 25km wide. The main earthquake (M7.8) generated a tsunami of about 30 cm which was recorded in Iskenderun and Erdemli, while small tsunami waves were recorded off the coast of Famagusta, in Cyprus. The authors of this study analyzed the modulation of solar activity in the hours and days preceding the Turkish seismic sequence to understand whether the five destructive seismic events recorded on February 6, 2023 were related to an increase in solar activity. Indeed, analyzing the variation of the density of the solar ion flux that hit the Earth between 4 and 7 February 2023 it was possible to ascertain that the Turkish seismic sequence was preceded by an increase in the proton density of the solar wind (**Fig. 2**), confirming the indications that the authors have communicated to the international scientific community since 2012 [2-6] [8-15] [17] [19] [22] [23] [25] [31] [32] [39] [43] [45-52] [55-62] [64] [66] [67], i.e. that the potentially destructive seismic activity (M6+) which is recorded on a global scale is always preceded by an increase in the density of the solar ion flux.

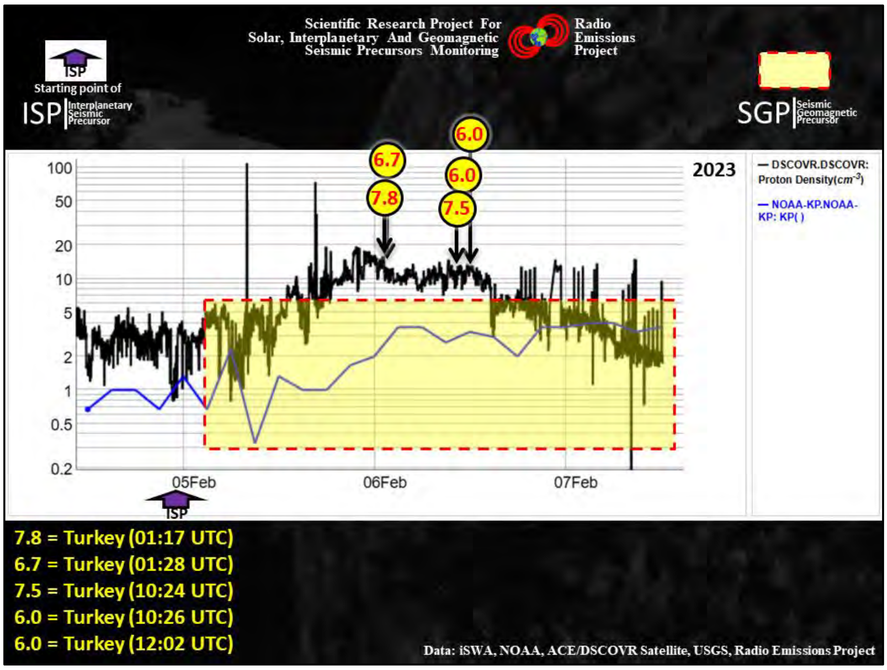

Fig. 2 - Solar wind proton density variation related to Turkish seismic sequence. *Graph contains the data on the variation of solar wind proton density recorded between 4 and 7 February 2023 at the L1 Lagrange point by Advanced Composition Explorer (ACE) Satellite and Deep Space Climate Observatory (DSCOVR) Satellite; the variation of Kp-Index and the temporal markers (black vertical arrows) of Turkish seismic sequence. 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 seismic sequence (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).*

Methods and data

To understand if the Turkish seismic sequence had been preceded by an increase in solar activity, the authors analyzed the characteristics of the solar ion flux (solar wind velocity, solar wind density, dynamic pressure, proton and electron density) through data provided by two artificial satellites located in L1 Lagrangian orbit (**Fig. 2-5**):

- Advanced Composition Explorer (ACE) Satellite.
- Deep Space Climate Observatory (DSCOVR) Satellite.

These data were subsequently compared with the times of destructive seismic events recorded in Turkey on February 6, 2023 provided by the United States Geological Survey (USGS) to understand whether there had been an increase in the solar ion flux density prior to the Turkish seismic sequence. The analysis of the low-energy proton fluxes from EPAM (Advanced Composition Explorer Satellite) (**Fig. 3-5**) made it possible to detect that the Turkish seismic sequence was preceded by an increase in the proton density of the solar wind which started on January 31, 2023 at 16:40 UTC and ended on February 6, 2023 at 13:00 UTC. The maximum peak was instead recorded on February 1, 2023 at 17:05 UTC.

By analyzing the data on the solar ion flux density provided by the Deep Space Climate Observatory (DSCOVR) Satellite (**Fig. 2**) it was possible to verify that the Turkish seismic sequence was preceded by an increase in the proton density of the solar wind which started on February 5, 2023 at 05:58 UTC and ended on February 8, 2023 at 08:18 UTC. In this case, the maximum increase was recorded on February 5, 2023 at 08:00 and was of the "impulsive" type, while the maximum "gradual" type increase was recorded between 19:20 UTC of February 5 2023 and 01:13 UTC on February 6, 2023.

Through these data it was possible to understand that the Turkish seismic sequence was preceded by an increase in the density of the solar ion flux as happened for all potentially destructive seismic events (M6+) recorded on a global scale since 2012 [2-6] [8-15] [17] [19] [22] [23] [25] [31] [32] [39] [43] [45-52] [55-62] [64] [66] [67]. The observed increase in solar activity translates into an increase in the density of the solar ion flux that has reached the Earth and subsequently determined an increase in Kp-Index. The data provided through the ACE and DSCOVR satellites made it possible to calculate the time intervals between the observed increases (Interplanetary Seismic Precursors) and the first destructive seismic event recorded in Turkey on February 6, 2023 (M7.8 earthquake recorded at 01:17 UTC):

- Using Advanced Composition Explorer (ACE) Satellite data: ~129 ore.
- Using Deep Space Climate Observatory (DSCOVR) Satellite data: ~19 ore.

The clear difference between the two-time intervals depends, as the authors have already had the opportunity to clarify, on the different unit of measurement used by the two satellites to determine the entity of the solar ion flux density. Using "p/(cm^2-sec-ster-MeV)" (ACE Satellite) it is usually possible to obtain larger time intervals, while using "cm^3" (DSCOVR Satellite) much more modest time intervals are obtained.
This allows us to consider the data provided by the ACE Satellite more convenient in the context of an innovative method of seismic forecasting based on the evaluation of the solar ion flux increases [2-6] [8-15] [17] [19] [22] [23] [25] [31] [32] [39] [43] [45-52] [55-62] [64] [66] [67].

Another data confirming the fact that the Turkish seismic sequence was preceded by an increase in solar activity is represented by Kp-Index (**Fig. 2** and **2b**): on February 5, 2023 at 09:00 UTC the Kp-Index begins to grow due to the interaction of the dense solar wind and the Earth's magnetosphere.

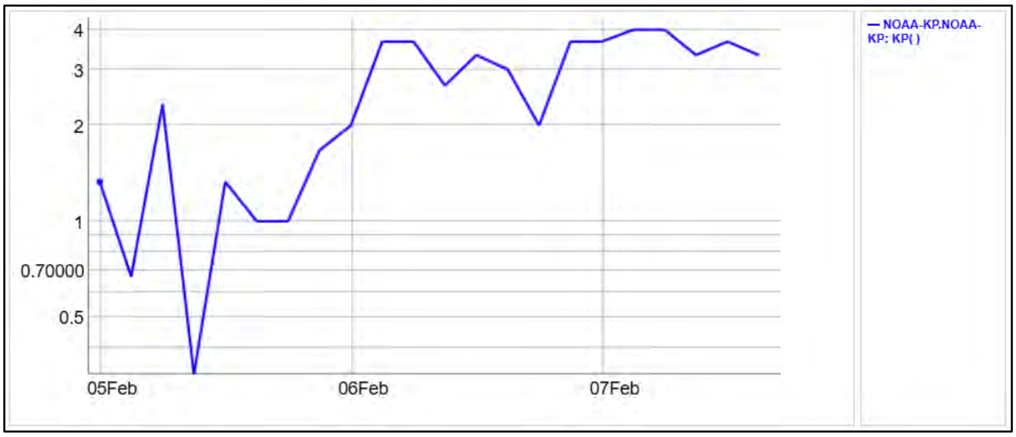

Fig. 2b – Kp-Index. *The graph above shows the trend of Kp-Index between 5 and 7 February 2023. Kp is an excellent indicator of disturbances in the Earth's magnetic field and is used by SWPC to decide whether geomagnetic alerts and warnings need to be issued for users who are affected by these disturbances. Credits: iSWA.*

When the increase of Kp-Index precedes a M6+ seismic event can be considered a seismic precursor. In fact, the authors observed this type of correlation for the first time in 2011 and conducted in 2012 the first large correlation study between geomagnetic events and M6+ global seismic activity. The first results of this study were published in 2013 [2]: the year in which the authors coined the term "Seismic Geomagnetic Precursors or SGP" to indicate any increase of a geomagnetic nature that precedes potentially destructive seismic events (M6+).

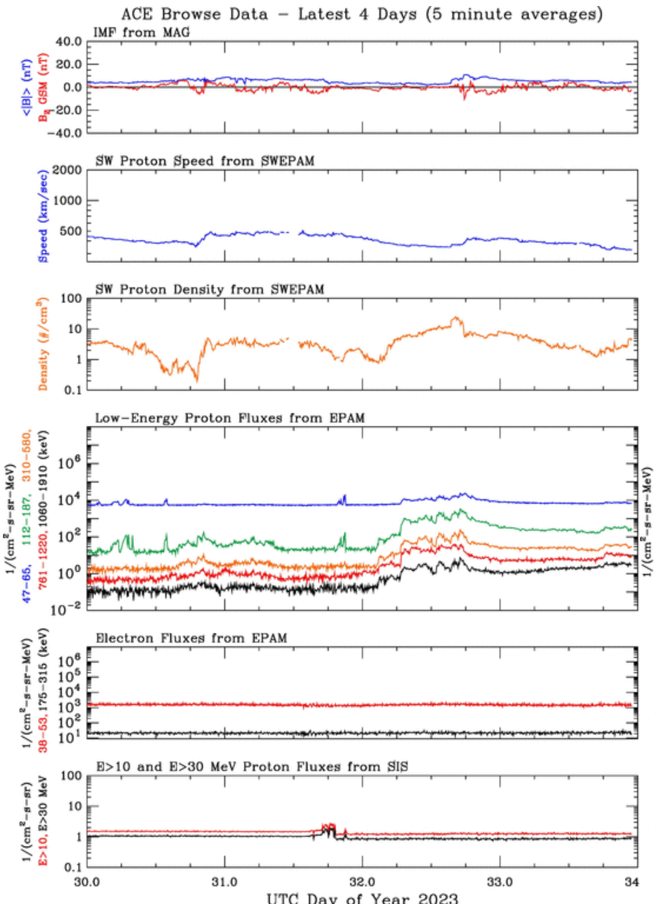

Fig. 3

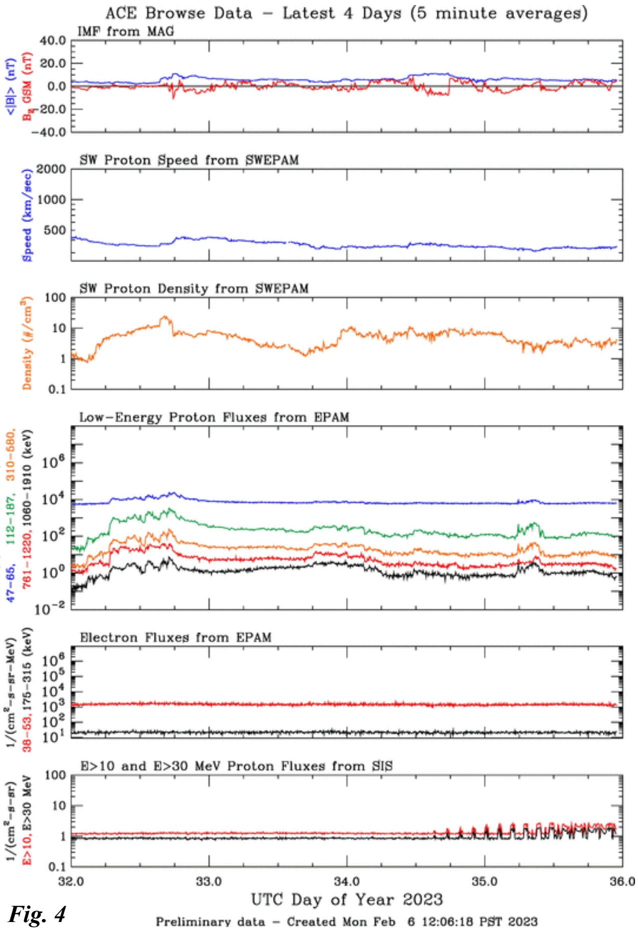

Fig. 4

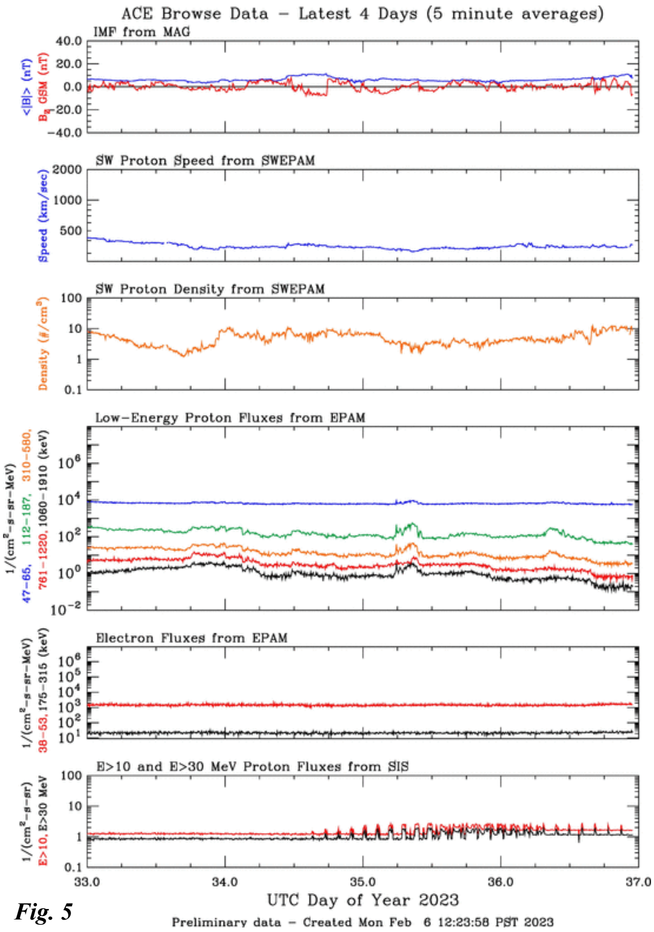

Fig. 5

Solar wind data. *The three graphs identified with the names Fig. 3, Fig.4 and Fig. 5 show the technical and physical characteristics of the solar wind recorded between 30 January 2023 and 6 February 2023 through the Advanced Composition Explorer (ACE) Satellite. Observing the graph, it is evident that the Turkish seismic sequence was preceded by an increase in the density of the solar proton flux which concerned the energy fractions 47-65 keV, 112-187 keV, 310-580 keV, 761-1220 keV and 1060- 1910 keV. Credits: Advanced Composition Explorer (ACE) Satellite.*

Another interesting data comes from the analysis of low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere (WINDMI) (**Fig. 6**). Through **Fig. 6** it is possible to notice that the Turkish seismic sequence recorded on February 6, 2023 occurred during an increase of AL-Index (started shortly after 00:00 UTC) which reached 400nT at ~09:00 UTC. This is also confirmed by DST-Index which reached a value below -35nT (weak storm).
More in detail, the first two M6+ seismic events recorded on February 6, 2023 (M7.8 earthquake recorded on February 6, 2023 at 01:17 UTC and M6.7 earthquake recorded on February 6, 2023 at 01:28 UTC) are were recorded approximately 30 minutes after the start of the Al-Index increase. The next two M6+ seismic events (M7.5 earthquake recorded on February 6, 2023 at 10:24 UTC and M6.0 earthquake recorded on February 6, 2023 at 10:26 UTC) were recorded after the maximum recorded increase of AL- Index. The last M6+ seismic event (M6.0 earthquake recorded on February 6, 2023 at 12:02 UTC) was instead recorded during a downturn of AL-Index overlapping almost exactly the maximum deviation recorded by DST-Index (a value lower than -35nT, compatible with a weak geomagnetic storm).

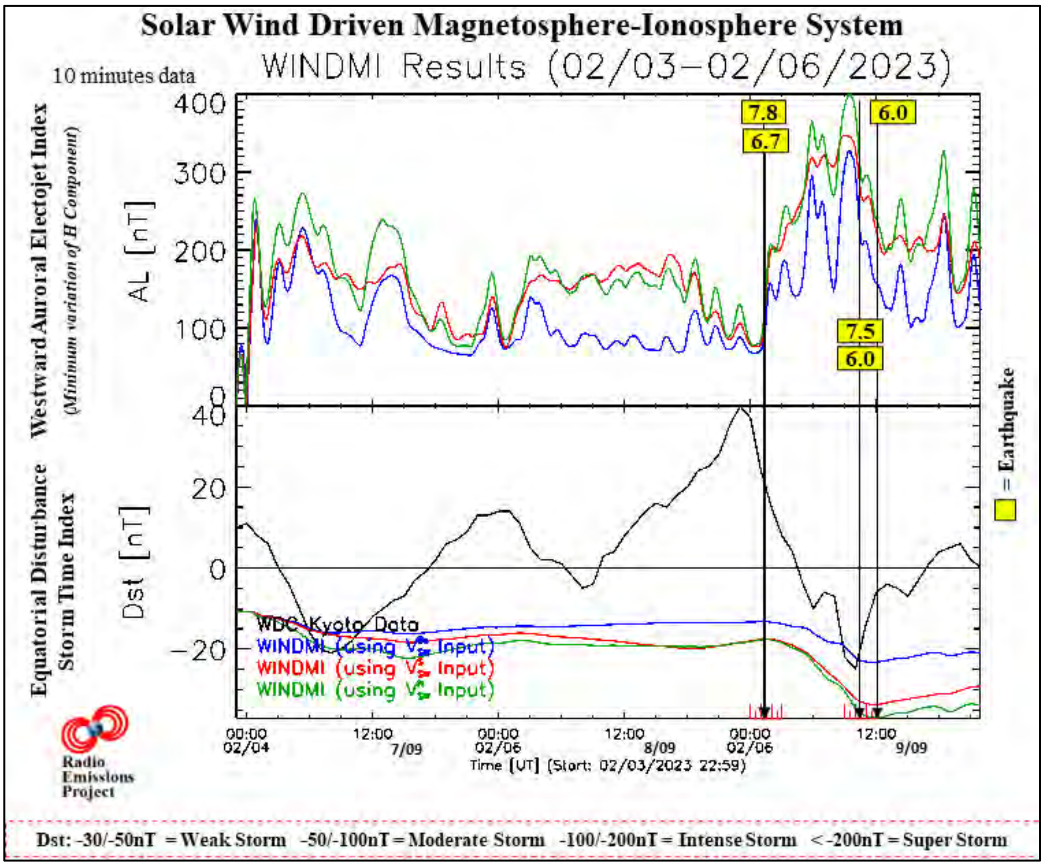

Fig. 6 - Low-dimensional model of the energy transfer from the solar wind through the magnetosphere and into the ionosphere (WINDMI). *The picture shows the variation of the AL-Index (at top) and the DST-Index (at bottom) in the hours that preceded the M6+ seismic sequence occurred on February 6, 2023. 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 Electrojet (WEJ) produced by increased of ionospheric currents therein present. The WINDMI data analysis showed that the Turkish seismic sequence occurred on February 6, 2023 was preceded by an increase of solar and geomagnetic activity. The black vertical arrow shows the temporal marker of the M6+ earthquake occurred on February 6, 2023. Model developed by the Institute for Fusion Studies, Department of Physics, University of Texas at Austin.*

RDF Monitoring

This study is based on data from environmental electromagnetic monitoring of the natural background carried out with an electromagnetic detection system developed by the authors in Italy: RDF (Radio Direction Finding) network active since 2017 [24]. This system employs a dual channel radio receiver designed to work efficiently between the SELF (Super Extremely Low Frequency) band and the first portion of the LF (Low Frequency) band to amplify received radio signals over a bandwidth of 48kHz (expandable) through two orthogonally aligned loop antennas. Subsequently, a computer is able to reconstruct the azimuth, the intensity and the emission frequency of the captured radio signals in relation to the time variable, and on the basis of these criteria spectrograms are produced. This system has repeatedly allowed the authors to detect radio emissions that have had an azimuth coherent with potentially destructive seismic epicenters (M6+) and, in some cases, areas of the Earth's crust were identified in advance where medium and medium-low intensity seismic events were subsequently recorded [26-31] [33-38] [40] [42-44] [53] [54] [65] [68] [69].

The RDF monitoring system was used by the authors to analyze the radio frequency a few days before and during the Turkish seismic sequence recorded on February 6, 2023. The survey data provided unique and precise indications on the natural radio emissions whose azimuth coincides with that of the M6+ seismic epicenters recorded in Turkey on February 6, 2023. The RDF monitoring stations used to carry out this study were the following:

- RDF Station located in Lariano (Rome) – Lat: 41.728799 N; Long: 12.843205 E.
- RDF Station located in Pontedera (Pisa) – Lat: 43.672445 N; Long: 10.640100 E.

Strong electromagnetic signals had been recorded on 31 January 2023 from the RDF station of Lariano, Rome, Italy, starting from 22:45 UTC (**Fig. 8**), with a strong electromagnetic peak in the SELF band (whose signal was observed between 0.001Hz and 7Hz). The intensity of this increase, which lasted 2 hours and 10 minutes, was then followed by an increase in the natural geomagnetic background at an electromagnetic frequency of 0.04 Hz, lasting for many hours. Following these signals, other electromagnetic emissions with an electromagnetic frequency of 30 Hz also appeared:

- 00:30 UTC del 1 Febbraio 2023.
- 01:45 UTC del 1 Febbraio 2023.
- 02:45 UTC del 1 Febbraio 2023.
- 03:50 UTC del 1 Febbraio 2023.
- 04:55 UTC del 1 Febbraio 2023.

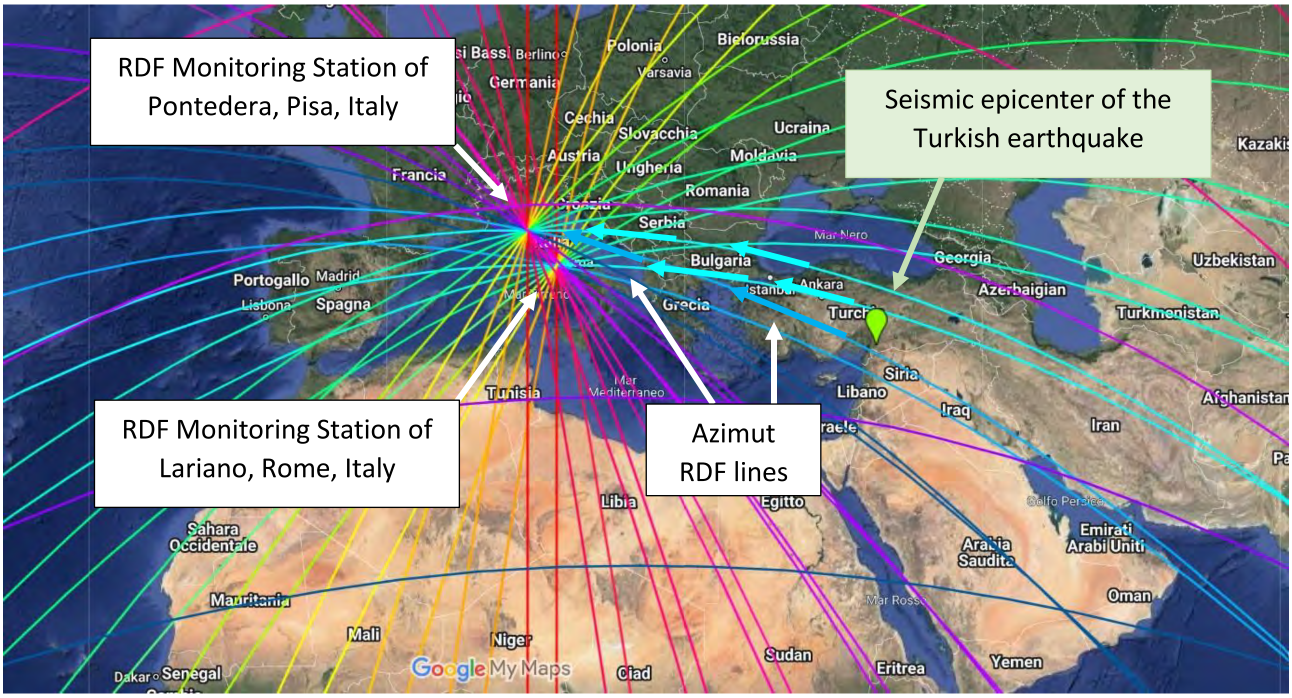

*Fig. 7 – **World mapping of the Italian RDF network, and the position relative to the seismic epicenter of the Mw 7.5 earthquake, which occurred in Turkey, 4 km SSE of Ekinözü**. The map highlights the azimuth lines of the RDF system developed by the Radio Emissions Project. Credits: Radio Emissions Project, Google My Maps.*

Important electromagnetic signals appeared for many hours, and for several days, before the strong Turkish seismic sequence was registered. **Fig. 8** and **9** show part of the spectrograms recorded by the Italian RDF network, which highlights the arrival azimuth of natural radio signals, coming from the geographical area of the Turkish seismic epicenter. **Fig. 9** shows the dynamism of the electromagnetic emissions recorded by the RDF station of Lariano (RM), between 2 and 3 February 2023, a strong increase in the geomagnetic background is evident at a frequency of 0.01 Hz, which appeared between 02:30 UTC and 07:00 UTC, and a new increase, with a frequency between 0.01 and 0.5 Hz lasting about 10 minutes. In that time, further radio anomalies appeared at a frequency between 25 and 35 Hz and at the following times of February 3, 2023:

- 02:25 UTC,
- 03:32 UTC,
- 04:40 UTC,
- 06:00 UTC.

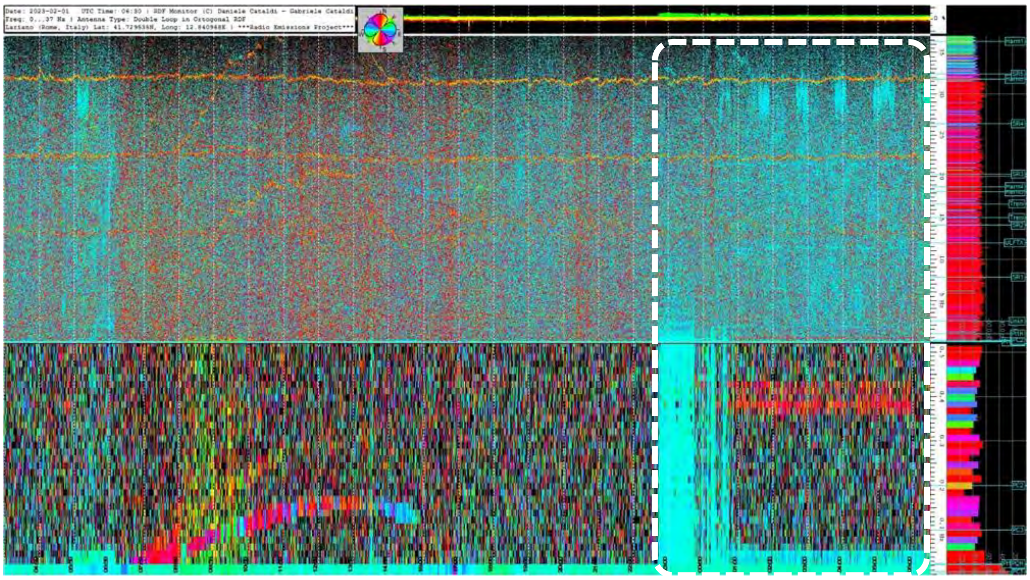

Fig. 8 – Dynamic spectrogram produced by the RDF monitoring station of Lariano, Rome, Italy, between 31 January 2023 and 1 February 2023. *The spectrogram above highlights the enormous electromagnetic increase that was able to saturate the natural electromagnetic background. Furthermore, the appearance of strong signals in the higher band is observed. On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions Project.*

Important electromagnetic signals appeared for many hours, and for several days, before the strong Turkish earthquake occurred. **Fig. 8** and **9** show part of the spectrograms recorded by the RDF network, which highlights the arrival azimuth of natural radio signals, coming from the geographical area of the seismic hypocenter.

Fig. 9 shows the dynamism of the electromagnetic emissions recorded by the RDF station of Lariano (RM), between 2 and 3 February 2023: a strong increase in the geomagnetic background is evident at a frequency of 0.01 Hz, which appeared between 02:30 UTC and 07:00 UTC, and a new increase, with an electromagnetic frequency between 0.01 and 0.5 Hz lasting about 10 minutes. In that time, further radio anomalies appeared at the frequency between 25 and 35 Hz and appeared at the following times:

- 02:25 UTC on February 3, 2023.
- 03:32 UTC on February 3, 2023.
- 04:40 UTC on February 3, 2023.
- 06:00 UTC on February 3, 2023.

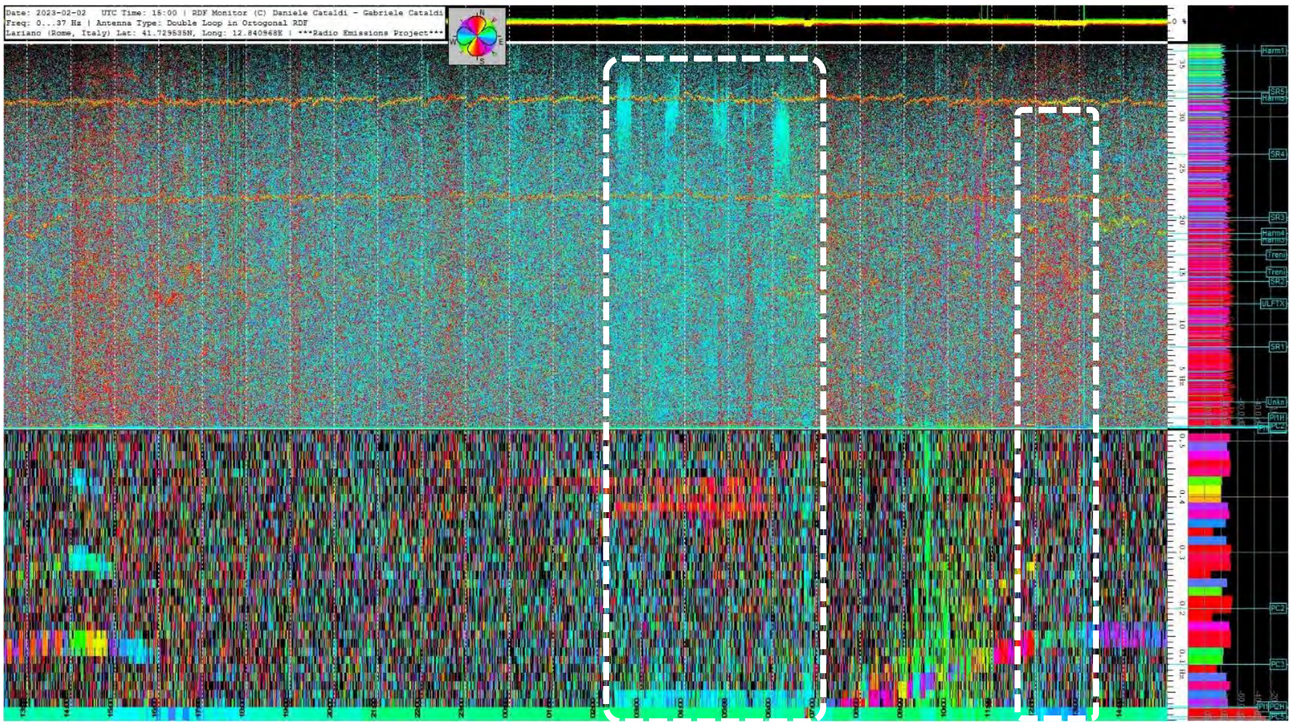

Fig. 9 – Dynamic spectrogram produced by the RDF monitoring station of Lariano, Rome, Italy, between February 1, 2023 and February 2, 2023*. It highlights the enormous electromagnetic increase capable of saturating the natural electromagnetic background, and the appearance of strong signals in the higher band. On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions*

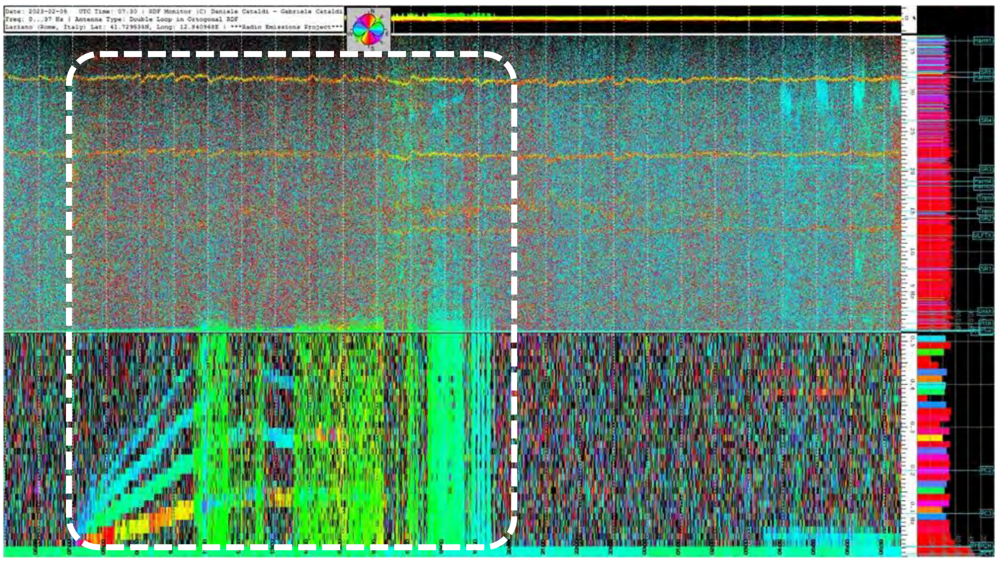

Fig. 10 – Dynamic spectrogram produced by the RDF monitoring station in Lariano, Rome, Italy, between February 1, 2023 and February 2, 2023*. It highlights the enormous electromagnetic increase capable of saturating the natural electromagnetic background, and the appearance of strong signals in the higher band. On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions Project*.

Also in **Fig. 9** there is an electromagnetic increase of natural origin between 0.001 Hz and 15 Hz (between 12:00 UTC and 13:10 UTC), the peak of which lasted for 5 minutes around 13:05 UTC of February 2, 2023. Other important increases then appeared on February 4, 2023 (**Fig. 10**). The most important increase ever

appeared at 07:00 UTC and ended around 19:30 UTC. In this case, **Fig. 10** shows this electromagnetic emission highlighted by the RDF station of Lariano, Rome, Italy.
The emissions in this case had a frequency between 0.02 Hz and 32 Hz. Also in this case, as for the emissions shown in **Fig. 8** to **Fig. 9**, the emissions had the azimuth of the Turkish seismic epicenter.

With greater precision we can understand how the enormous anomaly recorded on February 4, 2023, highlighted in **Fig. 10**, has shown the azimuth of the Turkish seismic epicenter, with a turquoise color tending towards blue. Further electromagnetic increases in the natural background were recorded in the following hours, around 03:30 UTC on 5 February 2023, with an electromagnetic frequency of 0.05 Hz, up to 08:00 UTC (**Fig. 14**). This increase was then followed by a series of visible electromagnetic increases up to a frequency of 30 Hz.
The strong radio anomaly recorded on February 4, 2023 was extremely evident to the authors as it could suggest the accumulation of a large amount of tectonic stress at a major fault. Rarely does the RDF network record such broad and intense signals.
As has been said, the epicenter of the seismic sequence that occurred in Turkey is located near the turquoise-blue color azimuth (**Fig. 7**), and in this case the triangulation took place thanks to the data provided by the RDF stations of Lariano and Pontedera: RDF data indicated a vast area between the Mediterranean Sea (Cypriot) and the Black Sea, therefore precisely in Turkey. The confirming element is represented by a series of very interesting electromagnetic increases recorded by the RDF station of Pontedera (Pisa, Italy) and located in the SELF-VLF band (0-15 kHz).

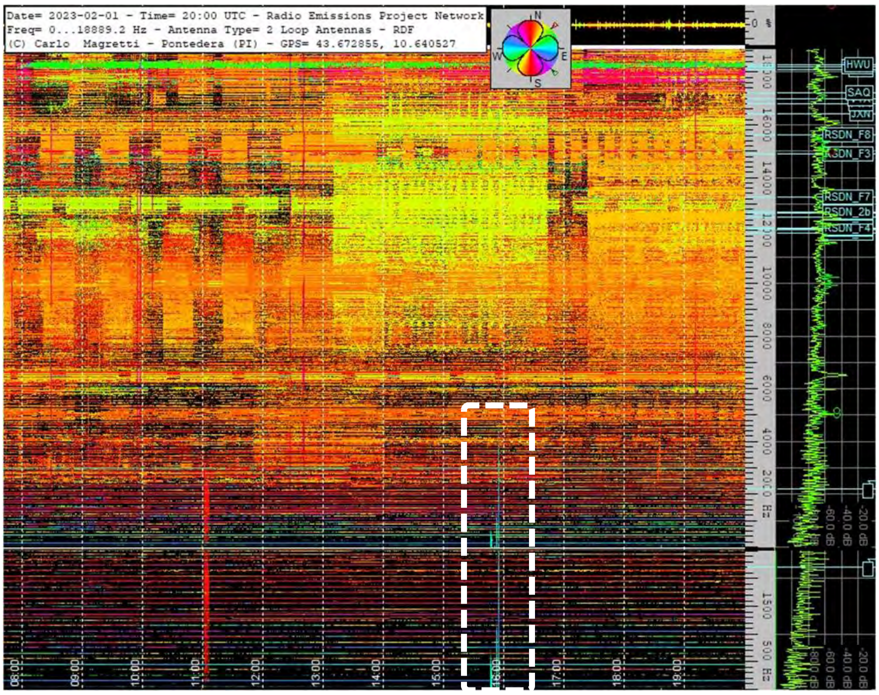

Fig. 11 – Dynamic spectrogram produced by the RDF monitoring station in Pontedera, Pisa, Italy, on February 1, 2023*. The spectrogram highlights electromagnetic signals, located on the natural electromagnetic background, from 0.0 to 5 kHz. On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions Project.*

Fig. 11 shows this electromagnetic increase (pulsations lasting a few minutes), which appeared between 15:45 UTC on 1 February 2023, with a frequency between 0.0 Hz and 5 kHz, also in this case these emissions, although not very evident at such a wide bandwidth, they had a turquoise-blue colouration, indicating the azimuth of the Turkish hypocenter, which occurred five days after.
The same radio anomalies, albeit with a lower bandwidth, then occurred on February 2, 2023, between 09:45 UTC of February 2, 2023, and at 16:10 UTC of February 2, 2023 (**Fig. 12**).

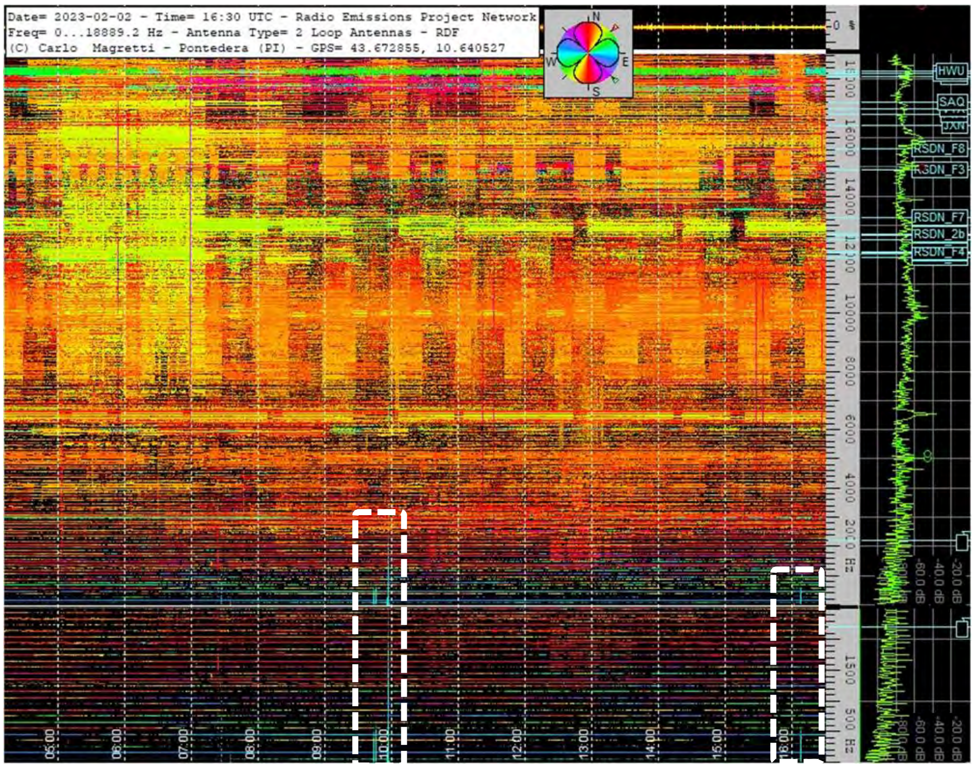

***Fig. 12 – Dynamic Spectrogram produced by the RDF monitoring station of Pontedera, Pisa, Italy, on February 2, 2023**. It highlights electromagnetic signals, located on the natural electromagnetic background between 0.0 and 2 kHz. On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions Project.*

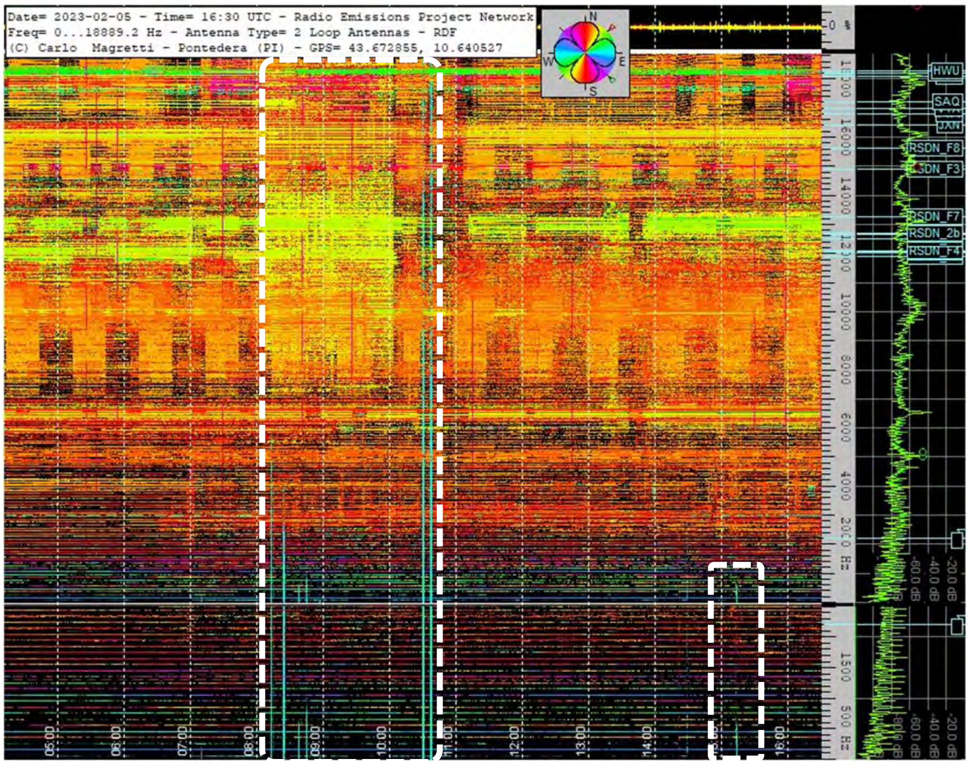

***Fig. 13 – Dynamic spectrogram produced by the RDF monitoring station of Pontedera, Pisa, Italy, on February 5, 2023.** It highlights electromagnetic signals, located on the natural electromagnetic background, from 0.0 to 18 kHz. On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions Project.*

The signals then reappeared close to the time schedule of the strong Turkish earthquake, and precisely (as visible in **Fig. 13**), between 08:00 UTC and 11:00 UTC on February 5, 2023, and again around 15:15 UTC also on February 5, 2023. Also in this case, these increases unequivocally suggested the accumulation of strong mechanical energy at the level of the lithosphere in the direction of the turquoise and celestial azimuths.

The electromagnetic signals recorded by the Italian RDF network between 31 January 2023 and 5 February 2023 highlighted the presence of strong natural radio emissions coming from the Earth's crust towards the Turkish area, 5 days before the Turkish seismic sequence was recorded. The RDF system highlighted these increases at a distance of about 2174 km, i.e. from the two Italian RDF stations.

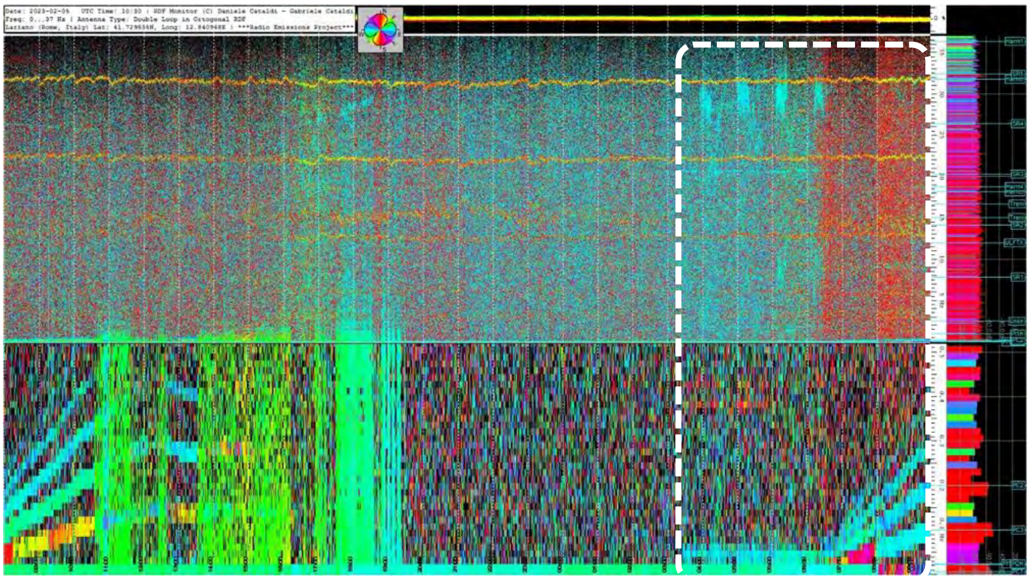

Fig. 14 – Dynamic spectrogram produced by the RDF monitoring station of Lariano, Rome, Italy, between 4 and 5 February 2023. *It highlights the enormous electromagnetic increase capable of saturating the natural electromagnetic background and the appearance of electromagnetic signals in the SELF-VLF band (0.00 Hz – 35 kHz). On the abscissa plane the spectrogram shows the timeline in UTC time, while on the ordinate plane the electromagnetic frequency of the recorded radio signals is visible. The different coloring shows the different azimuth (direction of arrival) of the recorded electromagnetic signals. Credits: Radio Emissions Project.*

Discussion

The analysis of solar activity and terrestrial geomagnetic activity, combined with the study of global seismicity, has allowed the authors to understand that there is a close correlation between the variations in the density of the solar ion flux (mainly proton density) and the (M6+) potentially destructive seismic activity occurring on a global scale [2-6] [8-15] [17] [19] [22] [23] [25] [31] [32] [39] [43] [45-52] [55-62] [64] [66] [67].
Unfortunately, in the current state of knowledge, the reason for this close correlation is not known: the authors have proposed some hypotheses over the years, focusing attention on the possibility that there is a form of electromagnetic interaction between the variations of the Earth's geomagnetic field and that part of the Earth's crust in which tectonic stress accumulates. According to this hypothesis, in fact, the accumulation of tectonic stress would lead to the formation of micro-fractures in the Earth's crust which are capable of producing an accumulation of electrical charges in the earthquake preparation area. It would be precisely this enormous concentration of electric charges (extended for tens, hundreds or thousands of km3) which would transform the Earth's crust into an electrically charged object capable of responding (mechanically) to variations in the Earth's geomagnetic field through the Lorentz force, altering, consequently, the static equilibrium of the faults. Even if this type of evidence has not yet been obtained, it is reasonable to consider it plausible especially following the results obtained by the authors since 2012 [2-6] [8-15] [17] [19] [22] [23] [25] [31] [32] [39] [43] [45-52] [55-62] [64] [66] [67]: all potentially destructive seismic events (M6+) recorded on a global scale have always been preceded by an increase in the density of the solar ion flux which subsequently interacted with the terrestrial magnetosphere. The same correlation was also observed against the Turkish seismic sequence recorded on February 6, 2023.

Another evidence collected by the authors in support of the hypothesis of the formation of microfractures (**Fig. 16**) in the preparation area of the earthquakes registered in Turkey on February 6, 2023 is represented by the analysis of the pre-seismic radio frequency through the monitoring network electromagnetic RDF (Radio Direction Finding).

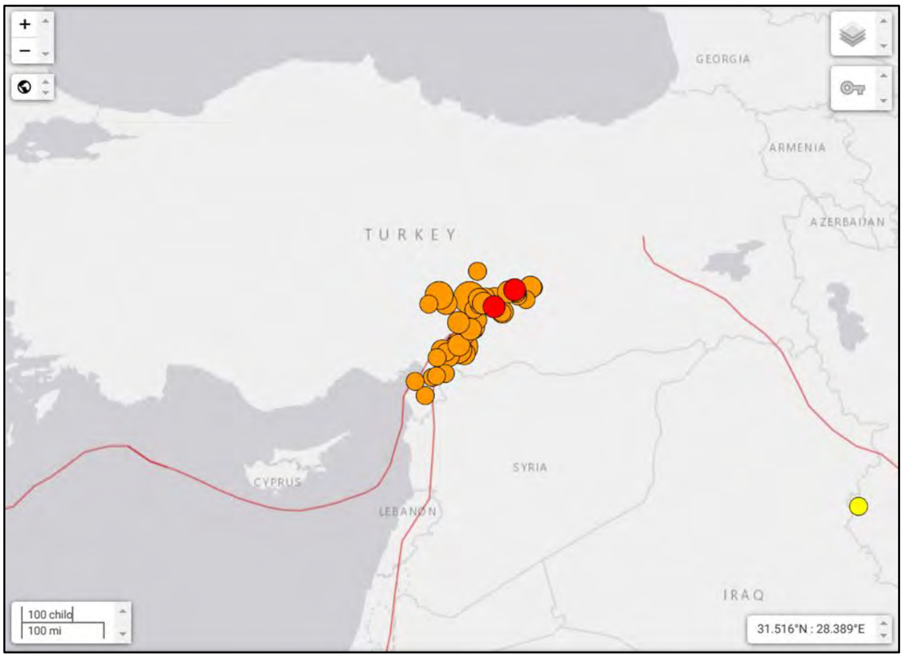

***Fig. 15 – Map of the seismic events that occurred in Turkey between 6 and 8 February 2023**. Credits: USGS.*

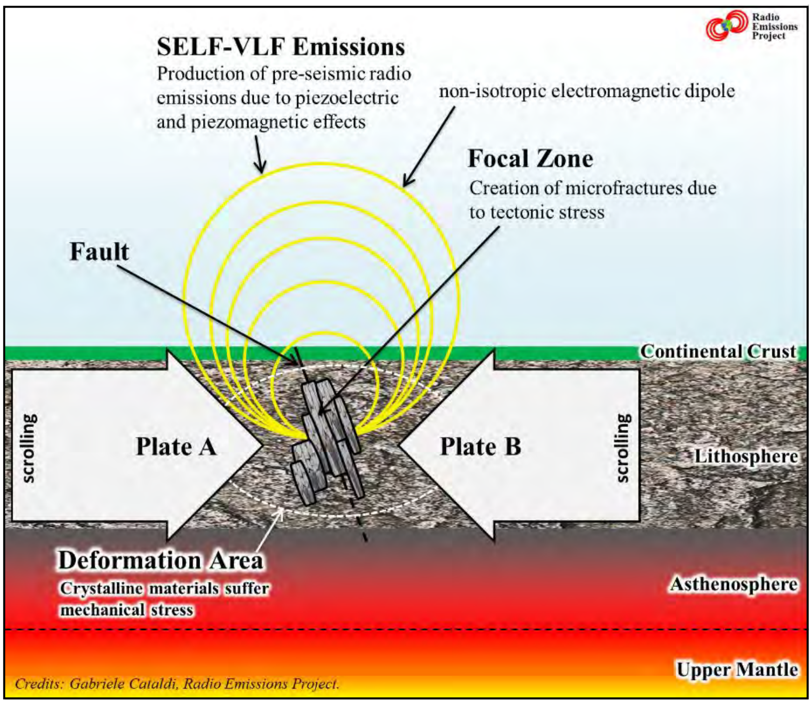

***Fig. 16 – Mechanism of pre-seismic radiofrequency production caused by tectonic stress**. Credits: Radio Emissions Project.*

Starting from 31 January 2023, the Italian RDF monitoring network began to record a series of electromagnetic increases having as arrival azimuth the geographical area in which the Turkish seismic sequence was subsequently recorded. The authors have ascertained that this type of radio frequency (whose spectrographic imprint is not compatible with electromagnetic signals of anthropic origin) appeared without any warning, presenting a high intensity compared to the natural electromagnetic background. According to RDF data, these pre-seismic radio signals (Electromagnetic Seismic Precursors or ESPs) came from the East of Italy (**Fig. 7**): azimuth compatible with the Turkish seismic area. **Fig. 15** shows the position of the Turkish seismic sequence recorded between 6 and 8 February 2023, and highlights how the area in which this seismic sequence was recorded coincides with the azimuthal direction indicated by the Italian RDF monitoring network, i.e. a strip of geographical area that extends between the Mediterranean Sea and goes in the direction of the Black Sea.

The RDF monitoring network has already provided on other occasions azimuth data compatible with geographical areas in which low, medium-low, medium and strong seismic events have been recorded [24] [26-31] [33-38] [40] [42-44] [53] [54] [65] [68] [69], and this has made it possible to obtain a lot of evidence in support of the hypothesis that radiofrequency can be produced in the earthquake preparation area following the creation of microfractures [1] [4] [7] [16-20] [23] [31] [43] [33] [63] [64] (**Fig. 16**). Radiofrequency that can be captured and analyzed to perform a crustal diagnosis.

Thanks to the RDF monitoring network created by the authors, it is possible to analyze the natural electromagnetic background to understand the azimuth of each single electromagnetic emission visible over a wide bandwidth and to perform a triangulation using the data of two or more RDF stations. This is just what was done for the Turkish seismic sequence registered on February 6, 2023.

Conclusions

The conclusions of this work confirm what the authors have been saying since at least 2012 [1] [2] [31] [43], namely that monitoring the solar ion flux density allows us to understand in advance when a recovery of solar energy is expected on Earth potentially destructive seismic activity (M6+). The average time interval calculated on the basis of data collected on solar ion flux and M6+ global seismic activity between January 1, 2012 and February 6, 2023, corresponds to ~103 hours. The Turkish seismic sequence recorded on February 6, 2023 was preceded by an increase in the solar ion flux density: this increase started some tens of hours before the Turkish seismic sequence (~19 hours earlier, if we consider the data on the ion flux provided by Deep Space Climate Observatory Satellite; ~129 hours earlier, if solar ion flux data provided by Advanced Composition Explorer Satellite are considered).

Furthermore, environmental electromagnetic monitoring (0-48kHz band), realized with RDF (Radio Direction Finding) technology, has been able to prove that there are areas of the Earth's surface where natural electromagnetic dipoles are generated before low, medium-low, medium and high intensity seismic events occur [24] [26-31] [33-38] [40] [42-44] [53] [54] [65] [68] [69]. The Italian RDF network identified an electromagnetic source located between Turkey and Syria about 5 days before the Turkish seismic sequence of February 6, 2023 was recorded. This result was obtained by analyzing the azimuthal data of the only two RDF monitoring stations installed in the Mediterranean area.

According to the authors, what has just been stated constitutes clear proof (not the only proof presented by the authors during their career) of the potential of solar activity monitoring and environmental electromagnetic monitoring (with RDF technology) in the field of seismic prediction. In fact, data on solar ion flux density provide an accurate indication of when a resumption of potentially destructive seismic activity on a global scale is expected [2-6] [8-15] [17] [19] [22] [23] [25] [31] [32] [39] [43] [45-52] [55-62] [64] [66] [67], while the only indication about the seismic district involved can be provided through the RDF data. Unfortunately, the current number of RDF monitoring stations installed on the Earth's surface is very small, and even less small is the number of RDF stations installed in the Mediterranean area. If a greater number of RDF stations could be available, the pre-seismic radiofrequency analysis would certainly be more efficient from an environmental point of view and more effective from a predictive point of view, since natural electromagnetic sources have the characteristic of not being of isotropic sources.

The challenge for the future is therefore represented by a substantial increase in electromagnetic monitoring stations implemented with RDF technology dedicated to the study of pre-seismic radiofrequency. The authors believe that this represents an important premise to improve this research project dedicated to seismic prediction: a project that has allowed to obtain truly significant evidence never obtained before by any other research project dedicated to monitoring possible precursor signals.

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