New Concepts in Global Tectonics Journal
Volume 12, Number 3, September 2024

ISSN number; ISSN 2202-0039

Space weather and pre-seismic radio frequency related to the Italian Mw 5.1 earthquake recorded on August 1, 2024

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Abstract. This study discusses the data collected by the Radio Direction Finding Network (RDF), compared with solar data, in the phases preceding the Mw 5.1 earthquake that occurred on August 1, 2024, in the province of Cosenza, Italy. The values, of an electromagnetic nature, fall within the category of natural origin radio signals, distinct from anthropogenic frequencies. The comparison between the two classes of candidate seismic precursors, which have been tested for over ten years, confirmed the trend observed in other earthquakes during the preseismic phases, with the appearance of magnetic anomalies starting five days before the earthquake. While solar activity studies may indicate potential global scale events, the data recorded by the Radio Direction Finding Network does not provide information on the direction of the earthquake epicenter relative to the monitoring stations. The earthquake under study confirms the trend of candidate precursors in the preseismic phases of seismic events with a magnitude equal to or greater than M5.

***Key Word*:** Italy, Seismic Precursors, RDF, Electromagnetic Signals, Prevision.

Introduction

Calabria is an Italian region characterized by a high seismic risk. This risk is attributed to its geological positioning and the complex network of active faults that traverse the area. Calabria is located in a convergence zone between the African and Eurasian plates, which results in frequent earthquakes of varying magnitudes.

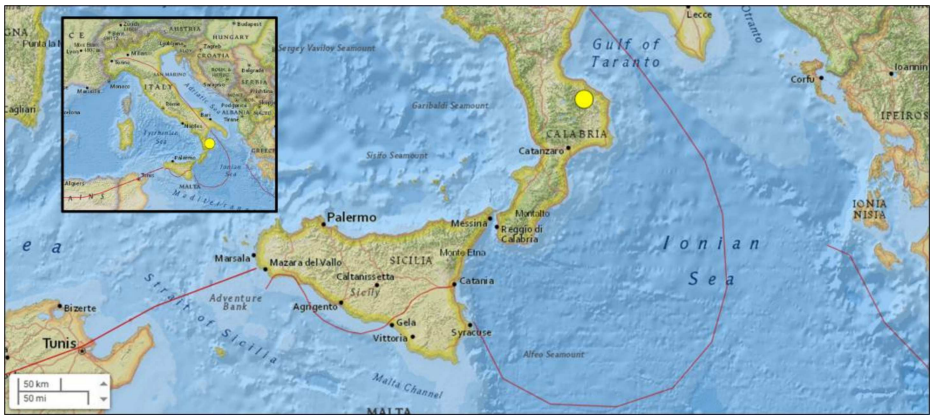

Fig. 1 Seismic epicenter of the Mw 5.1 event recorded in Italy. The upper part of the image shows he Italian seismic epicenter (yellow circle) of Mw 5.1, recorded on August 1, 2024, at 19:43:19 UTC. Credits: USGS.

Calabria is situated along the Calabrian-Peloritan Arc, a geologically active region that forms part of the collision system between the African and Eurasian plates. This arc is characterized by numerous active faults, which are the primary cause of earthquakes in the region. Historically, Calabria has experienced numerous devastating earthquakes [1]. Among the most notable is the 1783 earthquake, a sequence of shocks that struck the region, causing massive damage and loss of life. More recently, the 1908 Messina earthquake, which also affected southern Calabria, was one of the most disastrous

ISSN number; ISSN 2202-0039

events in Italian history [2] [3] [4]. Consequently, the event has been closely followed by major Italian news outlets due to its magnitude, which is uncommon in this period.

Method and data

This study was conducted by analyzing:

a) the data on the Italian earthquake provided by the United States Geological Survey (USGS);
b) the data provided by the Radio Direction Finding (RDF) electromagnetic monitoring system, developed by the authors and integrated into the electromagnetic monitoring network of the Radio Emissions Project. Specifically, data from the RDF monitoring station located in Lariano (RM), Italy, were utilized. This station is capable of monitoring the natural electromagnetic background across a 30kHz bandwidth, identifying its intensity, spectrographic footprint, and the azimuth of origin relative to the monitoring station;
c) the solar activity data provided by iSWA/CCMC.

This dataset was analyzed to identify variations in the background electromagnetic activity and changes in the density of the solar ion flux during the period preceding the Italian seismic event.

Electromagnetic signals

In the early stages of post-earthquake analysis, the research team from the Radio Emissions Project examined the electromagnetic recordings, identifying a highly interesting signal that appeared on July 27, 2024.

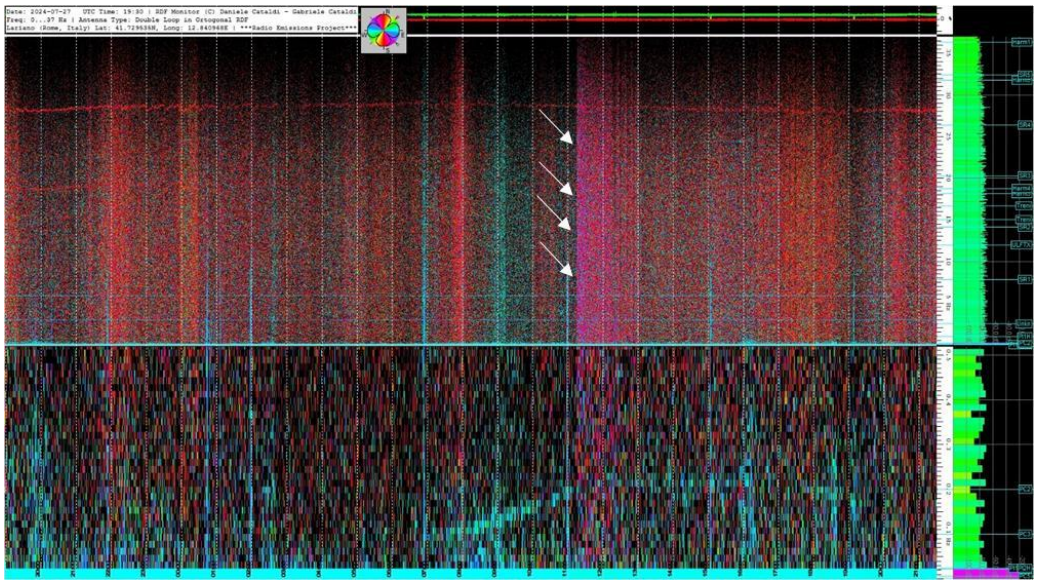

Fig. 2 Dynamic spectrogram recorded by the RDF station in Lariano, Rome, Italy, on July 27, 2024, at 11:10 UTC. In the upper part of the spectrogram, the appearance of a pre-seismic electromagnetic signal, marked in purple and highlighted by four white arrows, is clearly visible. The X-axis (horizontal) represents the timeline, while the Y-axis (vertical) shows the electromagnetic frequency of the radio signals, with the coloration depending on the azimuth of origin. The color saturation indicates the signal intensity: the higher the saturation, the stronger the signal, and vice versa. Credits: Daniele Cataldi; Radio Emissions Project.

This radio signal appeared around 11:10 UTC on July 27, 2024, and lasted for approximately 60 minutes (as shown in **Fig. 2**), after which it gradually faded. The electromagnetic frequency range in which this signal was observed was between 0.05 Hz and 34 Hz (SELF-ELF band). This very distinct signal indicated a specific azimuth relative to the city of Lariano, Rome, Italy, where the station is located. Indeed, when we examine the colorimetric mapping of the Italian RDF network (**Fig. 3**), we can see that the azimuthal lines visible on this map are of a purplish color, pointing in the direction

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of the seismic epicenter of the earthquake considered in this study (Mw 5.1 at 19:43:19 UTC, approximately 3 km west of Pietrapaola, CS, Italy).

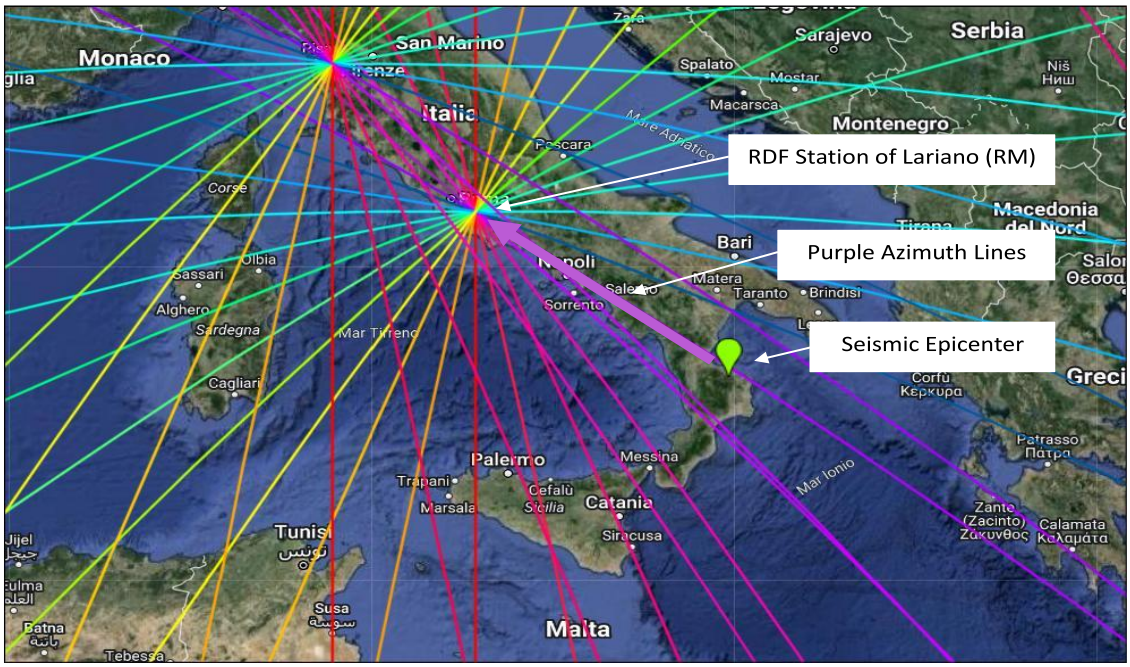

Fig. 3 Colorimetric map of the Italian RDF network. In the upper part of the image, the positions of the Italian seismic epicenter (Mw 5.1) and the RDF monitoring station located in Lariano, Rome, Italy, have been highlighted. Credits: Daniele Cataldi; Radio Emissions Project; Google My Maps.

It is evident that the purplish azimuth lines correspond to the area of the seismic epicenter, generated at the crustal level and propagated through the Earth-Ionosphere cavity, eventually being detected by the electromagnetic monitoring station in Lariano, Rome, Italy.

Solar activity

The analysis of solar activity has demonstrated that the Italian earthquake Mw 5.1, recorded at 19:43:19 UTC on August 1, 2024, was preceded by an increase in solar proton flux. This increase was recorded by two artificial satellites:

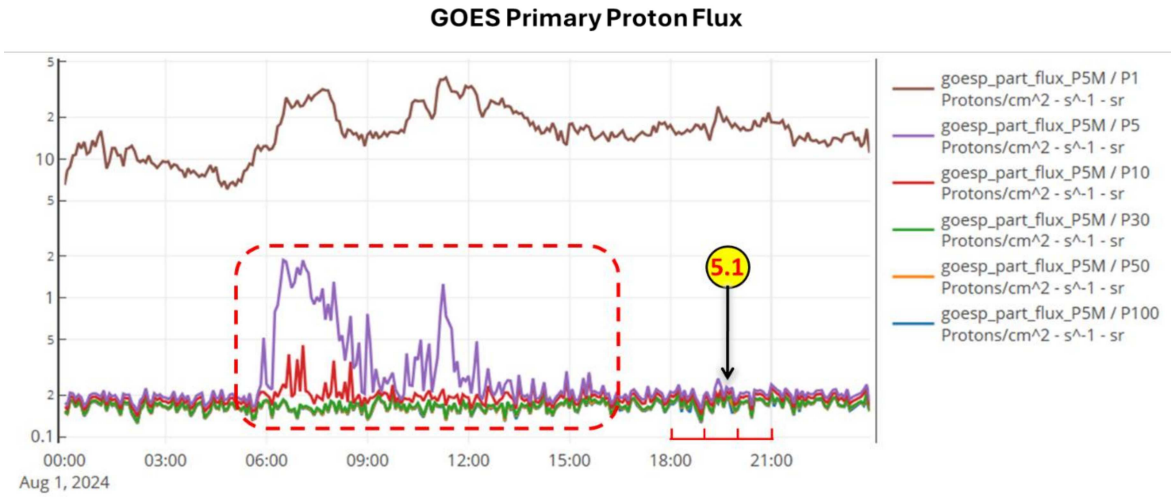

Fig. 4 Variation of Solar Proton Flux (GOES-18 Data) Correlated with the Italian Earthquake. The upper graph shows the curves of proton density variation detected by the GOES-18 Satellite. Each color represents a different proton energy fraction. The area identified by the red dashed line indicates the pre-seismic proton increase correlated with the Italian earthquake Mw 5.1 recorded on August 1, 2024. Credits: iSWA/CCMC.

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a) GOES-18 Satellite: located in geostationary orbit (**Fig. 4**);
b) Advanced Composition Explorer (ACE) Satellite: located in Lagrangian L1 orbit (**Fig. 5**).

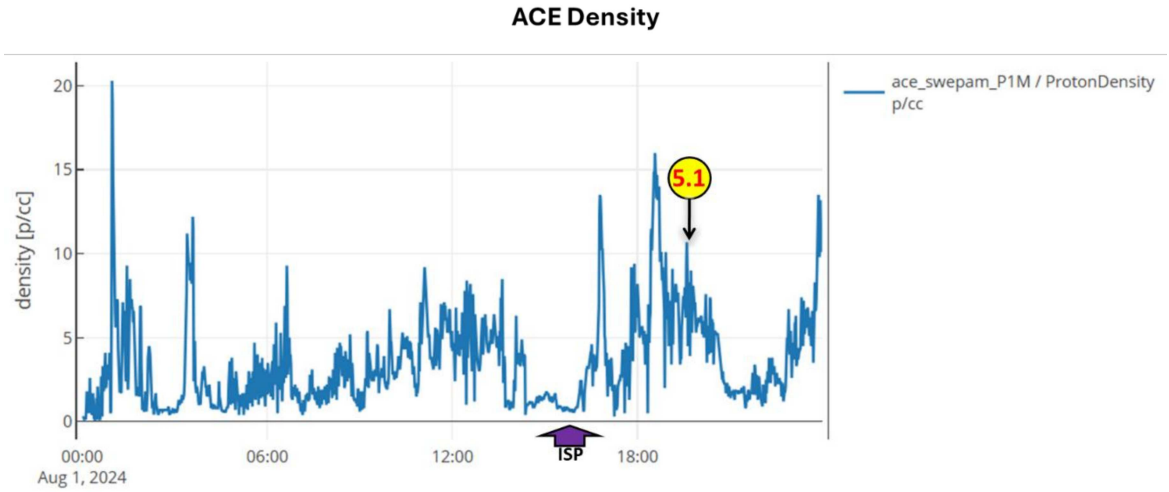

Fig. 5 Variation of Solar Proton Flux Provided by the Advanced Composition Explorer (ACE) Satellite. The upper graph shows the curve of proton density variation detected by the ACE Satellite on August 1, 2024. The proton energy fraction is equivalent to 1 MeV. The purple arrow identifies the beginning of the pre-seismic proton increase (Interplanetary Seismic Precursor – ISP) correlated with the Italian earthquake. Credits: iSWA/CCMC.

This series of data confirms what has been observed by the authors since 2011 and verified through a correlation study that has been ongoing for over 13 years. The results have been published and discussed multiple times internationally during this period. As early as 2013 [5], by analyzing solar activity data provided in 2012 by iSWA/CCMC, the authors understood that potentially destructive seismic activity on our planet is always preceded by an increase in solar proton flux interacting with the Earth's magnetosphere [6-7] [9]. This correlation has proven valid for every single potentially destructive seismic event (M6+) recorded globally [8] [10-47].

In this work, it was possible to correlate this type of interaction even for a lower magnitude seismic event, the Italian M5.1, demonstrating that increases in solar proton flux are correlated with a general resurgence of seismic activity on a global scale. This latest data has been observed by the authors multiple times from 2012 to the present [7] [22].

Discussion

The electromagnetic data obtained from the Italian RDF station highlighted the presence of a strong radio signal that appeared 5 days before the Mw 5.1 earthquake occurred in Calabria, Italy. This signal is unique because it was not present in the spectrograms recorded by the Lariano (RM) station before and is therefore closely temporally related to the earthquake, whose epicenter is geographically located along the purplish azimuth highlighted by the electromagnetic detection system developed by the authors. This type of correlation cannot be coincidental but indicates that the earthquake was preceded by low-frequency electromagnetic emissions that can be identified in advance. Regarding the solar activity data, it is evident that the solar proton flux increased before the Mw 5.1 seismic event recorded in Italy (**Fig. 4-5**), with a lead time of over 14.5 hours considering the data provided by the GOES-18 Satellite (**Fig. 4**) and a lead time of 3 hours and 43 minutes considering the data from the ACE Satellite (**Fig. 5**). This type of correlation, as mentioned in previous chapters, follows a temporal regularity never observed before in any other type of seismic precursor. Although the studies conducted by the authors on the correlation between solar activity and potentially destructive earthquakes have been almost exclusively dedicated to high-intensity seismic events (M6+), this study has shown that, evidently, this type of correlation can also be confirmed for earthquakes of magnitude lower than M6 [7] [22].

ISSN number; ISSN 2202-0039

Conclusions

The Italian RDF monitoring station recorded the appearance of a natural radio signal that indicated, five days in advance, the geographical location of an area in Italy where an earthquake of magnitude Mw 5.1 was recorded. The electromagnetic emission was well documented by the detection system developed by the Radio Emissions Project and highlighted how the radio signals were coming from a specific azimuthal direction, that is, the one where the Mw 5.1 earthquake was recorded. In this regard, it is possible to hypothesize that such electromagnetic emissions were generated in the earthquake preparation zone, probably through the phenomenon of piezoelectricity, following the deformation of the crystal lattices included in the fault plane and the formation of microfractures in the rocks, as proposed by many authors [21] [48-53].

Although, at the current state of knowledge, what has just been stated is only a working hypothesis, it is evident that the existence of radio signals correlated both temporally and azimuthally with medium and high-intensity seismic events cannot be ignored by the international scientific community. The same applies to the close correlation that exists between potentially destructive seismic events (M6+) and medium-high magnitude (M5+) and the variation of solar proton flux.

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