Seismic signals detected in Italy before the Nikol'skoye (off Kamchatka) earthquake in July 2017

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Abstract: This report presents a newly collected data of the electromagnetic signals detected in Italy, before two strong earthquakes (magnitude 6.4 and 7.7) on 17 July 2017 near Nikol'skoye, off Kamchatka, Russia. Changes in the electromagnetic background, detected by Radio Emissions Project in Rome, are associated to potential seismic precursor candidates. The monitoring Station in Rome analyzed from 2012 to nowadays and compared more than 800 earthquakes with magnitude greater than M6 on a global scale. The monitoring station showed characteristic electromagnetic signals in four frequency bands; the first from 0 Hz to 0.1 Hz, the second from 22 Hz to 30 Hz, the third 5.7 kHz, and the fourth 16.9 kHz. The data detected are similar to those collected in other strong earthquakes, 3-4 days before main shocks. Radio Direction Finding system by Radio Emissions Project is a new method of detection that allows to find the future epicenter zone that, in this case, provided encouraging data.

Keywords: *Nikol'skoye Earthquake, RDF System, earthquake precursor, proton density, solar wind*

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INTRODUCTION

On July 17, 2017 a strong earthquake, with magnitude Mw7.7, occurred 198 km ESE Nikol'skoye, in Russia **(Figure 1**). The seism was detected by USGS at 23:34 UTC (01:34AM Italian time) in front of Kamchatka Peninsula in the Bering Sea. This strong quake was preceded by another seism with magnitude M6.4 the day before. These geophysical events prompted us to detect the pre-earthquake signal from July 14, 2017, in Italy. The analysis is based on the comparison of data between Solar Wind Density and electromagnetic background, gathered by Radio Emissions Project (Straser et al., 2015-16; Cataldi et al. 2016-17; Sobolev et al., 2001; Odintsov et al., 2006) combined with new method RDF (Radio Direction Finding), already proposed in similar formula by (Ohta et al., 2013; Kasahara et al., 2008). The monitoring station Radio Direction Finding (RDF), placed near Rome, in Italy, equipped with radio-goniometric detection system, show us the future epicenter area and important electromagnetic variations before a seismic event.

Data

The data acquired and analyzed in this paper include the variation in ionic density of the solar wind (ACE, Advanced Composition Explorer), Solar Wind Density (ENLIL Heliosphere Ecliptic Plane), temporal monitoring of CME events or Solar Coronal Mass Ejections (ISWA), Solar Wind Velocity, Electron flux (NOAA/SWPC), Kp-Index (SWPC, Space Weather Prediction Center), geomagnetic variations (Northern Europe and the Russian Republic observatories; Radio Emissions Project's Station, near Albano Laziale and Lariano, Rome, Italy), and seismic activity on global scale in real time 24/7 (USGS, United States Geological Survey).

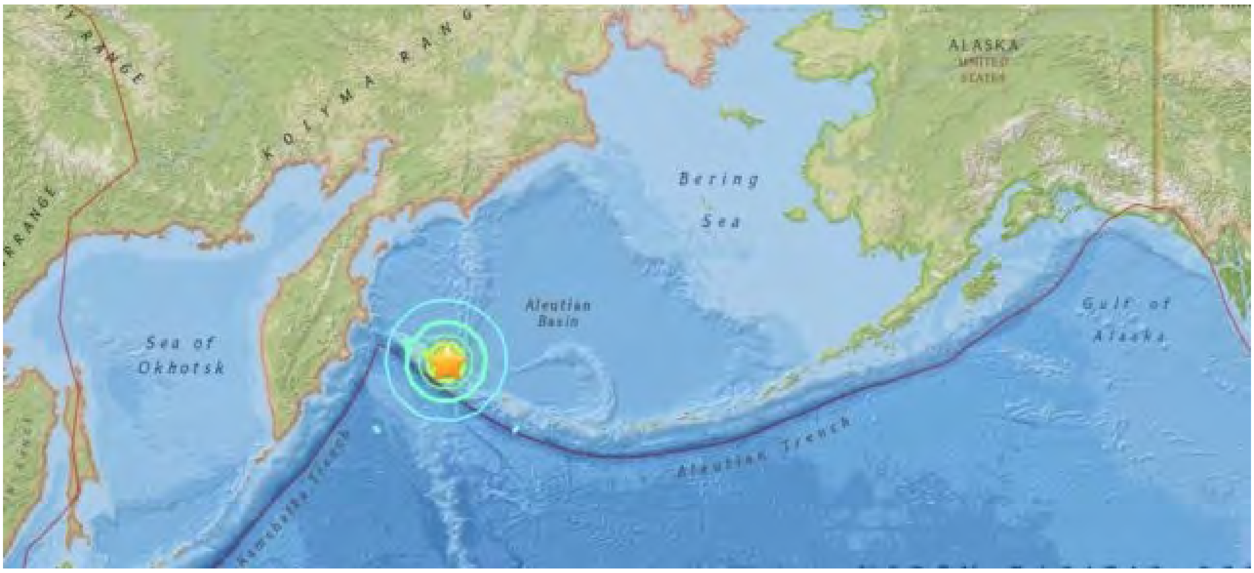

Figure 1. Index map, Nikol'skoye Earthquake epicenter zone

RDF System

Through a deterministic approach using statistical elements, the "Radio direction-finding" (RDF) detection method is being presented, which was developed recently in Rome (Italy), as part of the Radio Emissions Project. This is an innovative system for the detection of radio signals, in all probability generated by the rock under stress, and considered by the authors as a potential candidate for a pre-seismic precursor related to the earthquake epicenter.

This research project, specially dedicated to the study of pre-seismic radio emissions, is the only one of its kind to have been launched in Europe. However, in recent years, the reliability of RDF technology has been tested in Japan, e.g. in March 2011 (M9.0), which made it possible to locate the epicenter of the disastrous earthquake 5 days before the seismic event (Ohta et al., 2013).

Antenna

The antenna system of this electromagnetic monitoring station is based on two single Loop cars constructed, connected together and minimum size. They are oriented on the cardinal axes: the first on the N-S axis and the second on the E-W axis, so oriented at a 90° angle with respect to the two center axes of the antennas, in orthogonal pattern. The construction of the antennas has also provided thermal insulation in such a way as to lower the "noise" of radio signals, normally susceptible to thermal variations.

Receiver

The receiver was entirely made by Gabriele Cataldi, who took care of not only design but also real assembly. It is essentially based on the use of two low-noise chips that can receive data from the two antennas to convert the electrical signals from the antennas into a two-channel stereo (+ / - + +) signal.

Computerized System

The stereo signal is then conveyed to a PC that decodes through its sound-blaster thanks to a dedicated software: Spectrum Lab version: .2.90 b02. The latter converts the signals into spectrograms through a mathematical process called Fourier Transform. It allows to write a time-dependent function in the frequency domain, and to do so, decomposes the function in the base of the exponential functions with a scalar product. Saturation of colors: indicates their intensity, the more they appear discolored, the less the signals, the more intense they are, the greater their intensity.

Monitoring System

The source of electromagnetic emission could be found through the triangulation of received signals combining the direction of the signals.

The core of the identification system is based on "radio triangulation" or a technique that allows to calculate distance between points using the geometric properties of the triangles. Such technique is now used, for example, on the GPS detection system, or on the GSM tapping system. In essence, the receiving station is able to identify the goniometric axis of a radio signal and thus discriminate its direction of origin. With two or more receiving stations, it is possible to obtain the exact position of a radio broadcast and thus understand the distance as well as the intensity. The technique used by the Radio Emissions Project is therefore able to identify the position of a given radio signal and locate it by triangulation. This is a technique that is still largely used in the field of research on electromagnetic seismic precursors and geomagnetic seismic precursors.

REPORT

Already 96 hours before the earthquake, Radio Emissions Project was monitoring solar and geomagnetic activity. Solar wind caused protonic and electronic increases in the early hours of July 14 (**Figure 2**). The increases carried on until July 16, taking up to 20:00 UTC on 17 July, before slowing down. Just during the early stages of this decline in proton density, the earthquake occurred in Russia, following the mechanisms already described by Straser et al. (2015).

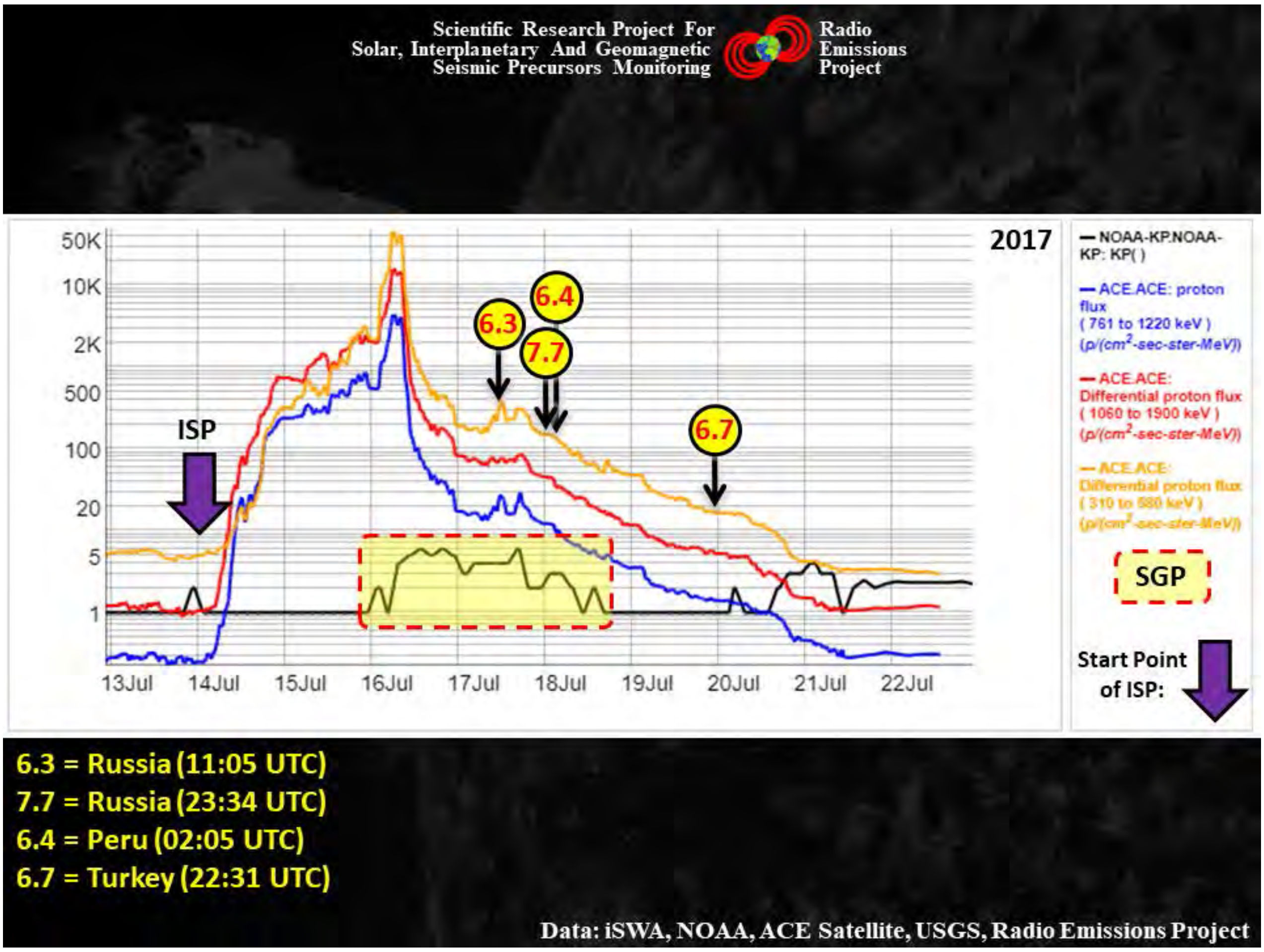

Figure 2. Solar wind proton density increase rise from 14 July to 17 July to 20:00 UTC. In the declining phase of the protons density, the earthquake Mw7.7 occurred.

Solar wind proton density

Solar wind proton density variation preceded the M7.7 Russia earthquake. The graph above shows the variation of the solar wind proton density that was recorded between 12 and 21 July 2017 by the Advanced Composition Explorer (ACE) Satellite, in orbit at L1 Lagrange point, at 1.5 million km from Earth, in the direction of the Sun (**Figure 2**). The energy fraction of the protons that was taken as reference was 761-1220 keV, 1060-1900 keV and 310-580 keV. The variation of the solar wind proton density was superimposed on the temporal data of the M6+ seismic events occurring on a global scale between 14 and 21 July 2017 (vertical black arrows). The beginning of the protonic rise (indicated by the big purple arrow) occurred at 00:00 UTC on July 14, 2017. On July 16 at 5:55 UTC the proton density reaches its maximum intensity and then gradually decreases in the following days. On July 17 at 11:45 UTC and at 17:30 UTC, the proton density had two more increments, but small in size, after which it returned to decrease regularly to return to basal level a few days later (July 21, 2017). In this period of time, after the main proton increase, four strong intense seismic events were recorded: 1) M6.2 in Russia; 2) M7.7 in Russia; 3) M6.4 in Peru; 4) M6.7 in Turkey-Greece. The first three Earthquakes listed above were preceded by a geomagnetic perturbation a few hours before that reached grade 2 (NOAA scale): this perturbation was highlighted in yellow with a dotted red line. The beginning of the protonic rise has been defined by the authors as "Interplanetary Geomagnetic Precursor" because it preceded the four strong seismic events between 17 and 20 July 2017: this is a phenomenon observed by the authors since 2012.

Solar wind velocity

The graph above shows the variation of solar wind velocity that was recorded between 15 and 18 July 2017 by the Advanced Composition Explorer (ACE) Satellite, in orbit at L1 Lagrange point, at 1.5 million km from Earth, in the direction of the Sun. The authors analyzed the solar wind velocity to verify if the Russian M7.7 earthquake that occurred on July 17, was preceded by an increase in solar activity and by an increase in geomagnetic activity: the beginning of the increase was recorded at 05:19 UTC on 16 July 2017 and coincided with the beginning of the peak that reached the proton density. The Russian M7.7 earthquake was also preceded by a series (at least 6) of impulsive increments of solar wind speed (recorded between 20:09 UTC and 23:34 UTC on July 17, 2017) that exceeded (in two cases) 770 km/s. This kind of correlation has been observed by the authors since 2012 (Straser et al., 2015). In addition, the data provided by the National Oceanic and Atmospheric Administration (NOAA) revealed that the M7.7 earthquake was preceded by two medium-intensity geomagnetic storms (G2).

PRE-EARTHQUAKE SIGNALS

July 14, 2017

The RDF system had begun to record an intense electromagnetic increase at 18:00 on July 14, 2017, when the system detected a variation of the natural geomagnetic background from -70 dB to -18 dB (**Figure 3**). This variation was very intense, from the geomagnetic background, appearing in red color. The RDF system, created by the Radio Emissions Project, is able to detect the direction of the electromagnetic densities of the natural geomagnetic signal, associating the directional (azimuth) with a precise color. In this case, red color were associated with these signals (**Figure 3**).

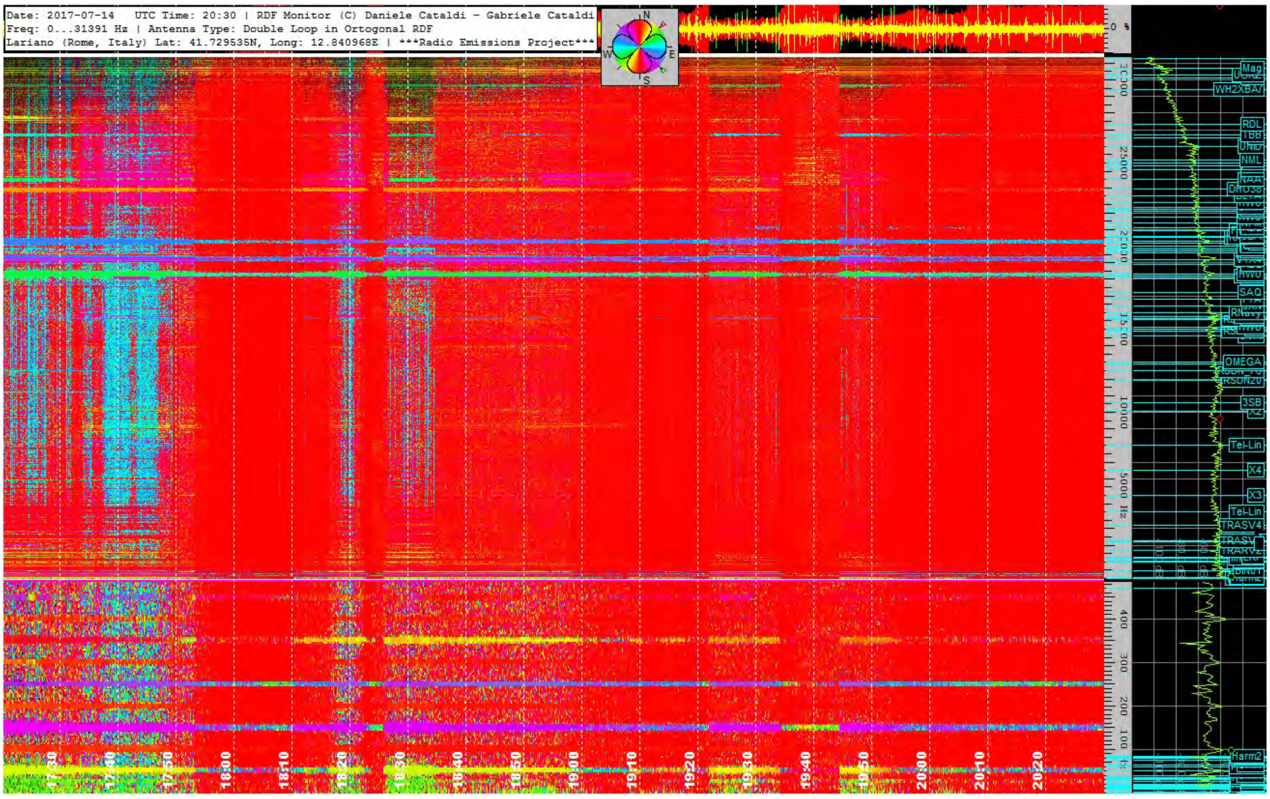

Figure 3. RDF Radio diagram - Radio Emissions Project. Increase of the geomagnetic background from July 14, 2017, at 18:00.

This increase in the geomagnetic signals of more than 50 dB was repeated impulsively, while the RDF system showed a continuous red signal, locate i.e. on the NS axis over the monitoring station, located in Italy (**Figure 4**). Even the "Plot Monitor" indicated particular variations in the appearance of that signal, referring to the radio-goniometric behavior of the observed geomagnetic background at different frequencies, including:

1. Noise from 0 Hz to 0.1 Hz.
2. Noise from 22 Hz to 30 Hz.
3. Noise at 5.7 kHz.
4. Noise at 16.9 kHz.

On such frequencies the degree of goniometric variation was very evident. The RDF system, however, had shown a variation of azimuth on the entire visible bandwidth between 0 and 32 kHz, with the appearance, as already mentioned of impulsive signals very detached from the geomagnetic background.

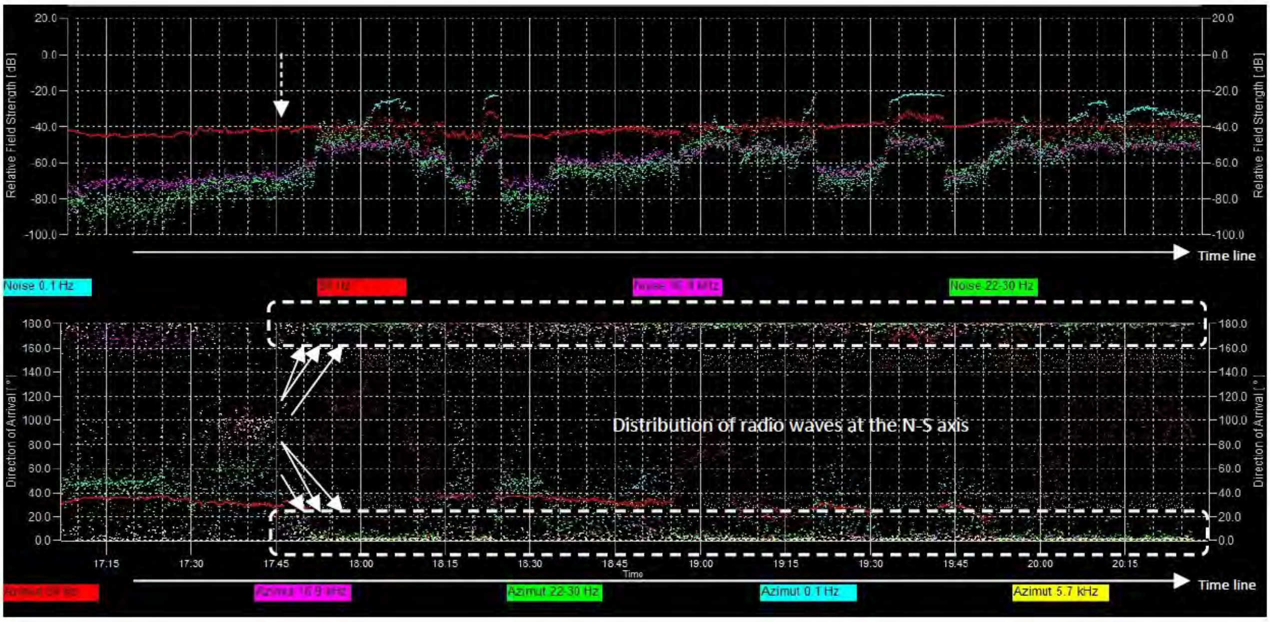

Figure 4. Plot Monitor RDF system - Radio Emissions Project. The electromagnetic signals and the variation of the azimuth signals received on July 14, 2017 are noticed from 18:00 onwards.

The data recorded on July 14, 2017 showed that the geomagnetic increase had undergone a fast distribution in the N-S direction (180 ° axis), compared to the monitoring station where the RDF system is placed. The strong geomagnetic increase, indicated by the electronic and computerized system, as an N-S axis signal, had lasted for a few hours, 21:25 UTC on July 14, 2017, i.e. 3.5 hours. At the same time, the "Plot Monitor" had also recorded the characteristics of the electromagnetic signals detected by the RDF system, not only evaluating its intensity and variation, but also the azimuth and their radio-goniometric behavior. The electromagnetic emission then disappeared, returning to the normal geomagnetic variations with a lower intensity, ranging from -75 dB to -90 dB.

During the following hours, no substantial increase in the geomagnetic background had been observed, with the features just described, intense and lasting over time.

The RDF system therefore indicated the origin of an electromagnetic signal located in a precise direction.

July 17, 2017

Three days after the appearance of this signal, a strong earthquake with magnitude Mw 7.7 occurred in the same direction indicated by the RDF system. The monitoring station had recorded in the meantime the entire frequency band from 0 to 32 kHz (**Figure 5**).

Figure 5. RDF Radio diagram - Radio Emissions Project. The increase recorded between 18:10 UTC and 20:42 UTC of July 16, 2017. This increase preceded the M7.7 earthquake of approximately 28 hours. In addition, this increase represents the most intense increase recorded by the RDF station in the last 28 hours. Calculating the phase shift of the azimuth recorded in all earthquakes located at a distance from the RDF station, the color of the increase is compatible with the azimuth of the earthquake M7.7.

CONCLUSIONS

One of the problems about the seismic precursor candidates is to choose the magnitudes to measure to receive indications, with sufficient time in advance, on the future epicenter zone, the occurrence period and earthquake's magnitude. The method presented in this report joins all three conditions, but we cannot yet to talk about the reliability of the measurements of the earthquake precursors.

The Russian quake allowed to verify potential relationship between solar activity and seismology, and this link is already observed in more than 800 earthquakes M6+, from 2012 to nowadays by the authors. The Russian earthquake happened after the peak in proton density of solar wind. In the near future, through improvement of RDF monitoring system, will be possible to define the future epicenter zone.

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