PAPER 002

THE INTERNATIONAL ASSOCIATION FOR RESEARCH ON SEISMIC PRECURSORS (IARESP) ACTIVITIES AND RESULTS DURING THE 2016-2017 EARTHQUAKES IN ITALY

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ABSTRACT

A wider approach to the Radon precursor method is proposed, based on results from a network of several multiple ground monitoring stations. The intensities of Radon emissions recorded by the network are not the only factors to be considered; Radon pulses, which are otherwise systematic in shape and time of occurrence, are analysed in real time. Measurements carried out during the recent earthquakes in August and October 2016, and January 2017 show an evident correlation between occurrence of major earthquakes in the zone and radon peaks.

Key words: Radon emissions, earthquakes, radon peaks

INTRODUCTION

The physical mechanism of earthquakes and precursors is at present poorly understood, because the factors and conditions governing them are very complex. Therefore, it is necessary to investigate and understand the formation mechanisms of earthquakes in order to anticipate well in advance their disastrous effects.
Large earthquakes (M 5.5 or greater) are the most devastating of all natural calamities to human life and property. The recent earthquakes in Abruzzo, Italy (2009, 2016, 2017) have had tragic consequences for Italy.
At international level, several seismic monitoring networks, just based on seismic accelerations, are being utilized all over the World. However, any sort of multi-parametric monitoring method that takes into account the simultaneous observation of different precursory phenomena does not exist yet.

Precursors, radon, and the iAReSP activity and project
To this date, no reliable method has been developed for the successful application of earthquake prediction, based on a human scale. Nevertheless, based on long-term studies, some earthquake precursors, and in particular radon emissions, have been identified, and studies began to appear since several decades [1-8]. However, most of these precursors are subject to so many different influences that they behave erratically and therefore have been poorly understood so far, making earthquake prediction a controversial issue. Then, the detection of earthquake precursors and the development of early warning systems can be possible just through the simultaneous detection of multiple parameters. In the last decades several laboratory tests and experimental observations evidenced that mechanical, electromagnetic, and neutron emissions, together with radon levels and carbon dioxide emanations are the most reliable natural phenomena that can be linked to earthquake preparation.
If a strong correlation between these different physical quantities and the progressive stages of the imminent earthquake will be scientifically demonstrated, an undoubtable impact onto geophysics and seismology will be produced.
The following earthquake precursors have been identified:

- Radon emissions from rocks and waters,
- Change in ion concentration in water,
- Variation in concentration of He, Ne, Ar, and N2 in the environment of the affected zone,
- Abnormality of behaviour in some animals,
- Occurrence of milder foreshocks before a large earthquake,
- Sudden water-level change in some wells,

- Ground deformation, stress build-up in rocks (which may in turn alter electric resistance of the rocks), etc.

Major, erratic changes in Radon concentration have been observed in many earthquake-prone zones a few months/days before, during and after a large earthquake [2,3,5-7, 10-13].

Such behavior has been observed in deep mines, cellars and wells where induced Radon concentration fluctuations due to disturbing environmental factors can virtually be ruled out.

Therefore, it is tempting to consider a sudden erratic fluctuation in Radon concentration, for days on end, particularly in deep wells in an earthquake-prone zone, as a potential omen for an earthquake.

A standard explanation for the variation in dissolved Radon concentration in faults and water wells before, during and after an earthquake in that zone, is the following:

Variation in release of the gases entrapped in crustal rocks due to pore collapse and/or opening of micro-fractures caused by stress variations.

The iAReSP (International Association for Research on Seismic Precursors) research activity is dedicated to verify the relationship between radon and other environmental parameters variations and the occurrence of earthquakes, including spatial indications of where the earthquake epicenter could be located. The Tellus project is devoted to study, on the basis of data detected from the ground, what happens during the phase preceding an earthquake [9,14,17,18]. iAReSP has designed and built two monitoring stations in Central Italy (Pizzoli and Cagnano Amiterno, L'Aquila Province, see figures 1-5), that include:

- capacity to detect the emission of radon;
- measurements variation of electric and electromagnetic fields;
- detection and use of several meteorological parameters (e.g. temperature, pressure, and humidity);
- camera with optical vibration technology.

The two stations are part of a network in progress. The network will ensure the monitoring of an area of approximately 600 km2, in the most critical area in Italy for earthquakes: l'Aquila Province, Abruzzo Region, Central Italy.

The method of Continuous Radon Monitoring (C.R. of EPA) is used to measure indoor Radon concentration [17,18]. The air is diffused into the ionization chamber, in counting mode. Scintillation counts are processed by electronic equipment, and radon concentrations for predetermined intervals are stored in the instrument's memory.

This detection category includes devices that record real-time continuous measurements of radon gas over a series of minutes and report the results in hourly increments. The counted anomalies of number of pulses are automatically identified with our specific software and correlated to the measurements of the other parameters (Davis Vantage Pro2 weather station software).

Thus, we are able - in real time - to show the anomalies that would hardly be identifiable with the single view or with a normal data flow control, and we can tell which ones are not seismic precursors. Variations in Radon emissions do not only depend on earthquakes, but also on the combined effects of luni-solar tides, on winds, on the humidity, the temperature, the atmospheric pressure, volcanic activity, cosmic radiations, all disturbances which must be filtered and eliminated before hoping to detect variations due to telluric events.

Measurements in 2015-2017

Early results of the Tellus Project and of Pizzoli station will be summarized here first. During the starting measurement periods (late 2015, early 2016), no major seismic event was detected near the detection point: strongest earthquakes, recorded in that period, occurred at relevant distances from the station. Radon anomalies detected over the examined period were all caused by different factors, not related with earthquakes. In all the cases, being able to measure other outdoors parameters as temperature, pressure, and wind speed, it turned out clearly that those changes in the Radon Emissions coincide with the change in weather and in particular the atmospheric pressure and wind speed.

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During the survey from November 2nd to December 14th, we detected three major anomalies. In all the three cases, being able to measure other outdoors parameters as temperature, pressure, and wind speed, it turned out clearly that those changes in the Radon emissions coincide with change in the weather and in particular the atmospheric pressure and wind speed. Those collected data, with a time series of greater length, are useful to study the relationship between Radon concentration and atmospheric variables. The main cause of the inflow of radon turned out to be the pressure difference, which is created between outdoors and indoors. During the period of measurement of the emission of Radon, we have not measured any anomalies, except those caused by meteorological factors, which we

have been able to individuate and discard. We have recorded no false positives, and that is the main scientific result of this first survey period. For the moment, we have recorded no false negatives too, because the seismic activity was absent or of very low magnitude and there were no "significant" anomalous radon emissions.

Further measurements have been carried out during the recent earthquakes in August and October 2016, and January 2017. The results of the Pizzoli station show an evident correlation between occurrence of major earthquakes in the zone and radon peaks. They are available in figures 6, 7 and 8 and will be briefly discussed here.

On August 24, 2016, a strong earthquake (Mw 6.0), that has destroyed the Amatrice village in Central Italy and caused the death of 295 people, hit the center of Italy. The earthquake that struck Amatrice produced a seismic sequence of about 5,000 replicas over the first 10 days. Despite the high number of events, the total released energy does not reach that of the main shock.

Pizzoli's iAReSP-Tellus Project multidisciplinary station is about 30 km away from the epicentral point of the main earthquake of August 24, but is on a different seismogenetic structure, albeit close to the fault that produced the great earthquake. The station – as specified above - has a radonometer with ionizing chamber. Decays are measured in real time and averaged every 10 minutes. Thanks to these measurements, we have been able to measure the emissions of radon gas and to check their momentum in a very narrow radius around the station, about 10 km. Figure 6 shows the chart from 8 August to 3 September 2016. These data are being analyzed, to assess whether the two obvious anomalies (A, B after the earthquake) directly correlate with the earthquake itself (red line).

One of various assumptions is the following: the structure that generated the earthquake started a few days earlier with the breaking phase, also disturbing the Pizzoli fault, and generating an increase in the radon gas release activity. When the earthquake occurred, the station turned off due to lack of electricity and was restarted early in the afternoon. In that moment, the radon values were very high due to, in all likelihood, the strong strains on the Pizzoli fault due to the passage of the seismic waves of both the main shock and the strong immediate replicas.

It is evident the great importance of establishing a detection network with stations close to each other, as indicated and provided by the Tellus Project, with the aim of monitoring the territory from different points and obtaining confirmations or denials of anomalies that may or may not result due to an earthquake.

On October 30, 2016, a violent 6.5 Mw earthquake again hit the center of Italy: luckily, but not surprisingly, no casualties were counted this time. That was a new devastating earthquake, the strongest since 1980 (Irpinia, Mw 6.9): it released about 5 times more energy than the August 24th Mw 6.0 earthquake in Accumoli.

The station / epicenter distance was – this time - Km 49.2, almost double than the one of the August 24th earthquake. In this occasion, too, signals have been recorded, and they are of great interest (Figure 7). The graph includes a long period from October 10 to November 5, which shows an anomaly on October 27 and 28, that is, a few days before the strong earthquake whose arrival time is indicated by the vertical red line (06 am : 40 UTC of 30/10/2016).

These signals will be analysed, to ascertain that this is not simply a random correlation. However, the Radon222 that the station measures is exclusively that which comes out of the subsoil at the exact point of measurement and, from the geophysical point of view, it is exclusively the gas possibly produced by the cracks or micro-cracks of the fault of Pizzoli. In the multidisciplinary station, we have many other factors, which may have interfered with the measurement of radon: that is why it is important to thoroughly analyze the data, before confirming the presence of a real seismic abnormality.

Finally, another strong earthquake struck central Italy on January 18, 2017: in a few hours there were four earthquakes greater than Mw 5.0 with maximum magnitude Mw 5.5. The epicenter was at 9 kilometers from Amatrice. Minor and major earthquakes were recorded by the Pizzoli station again. In this occasion too (figure 8) radon emissions data in the Pizzoli station, and their correlation with the earthquakes timing are of extreme interest, and are currently under investigation.

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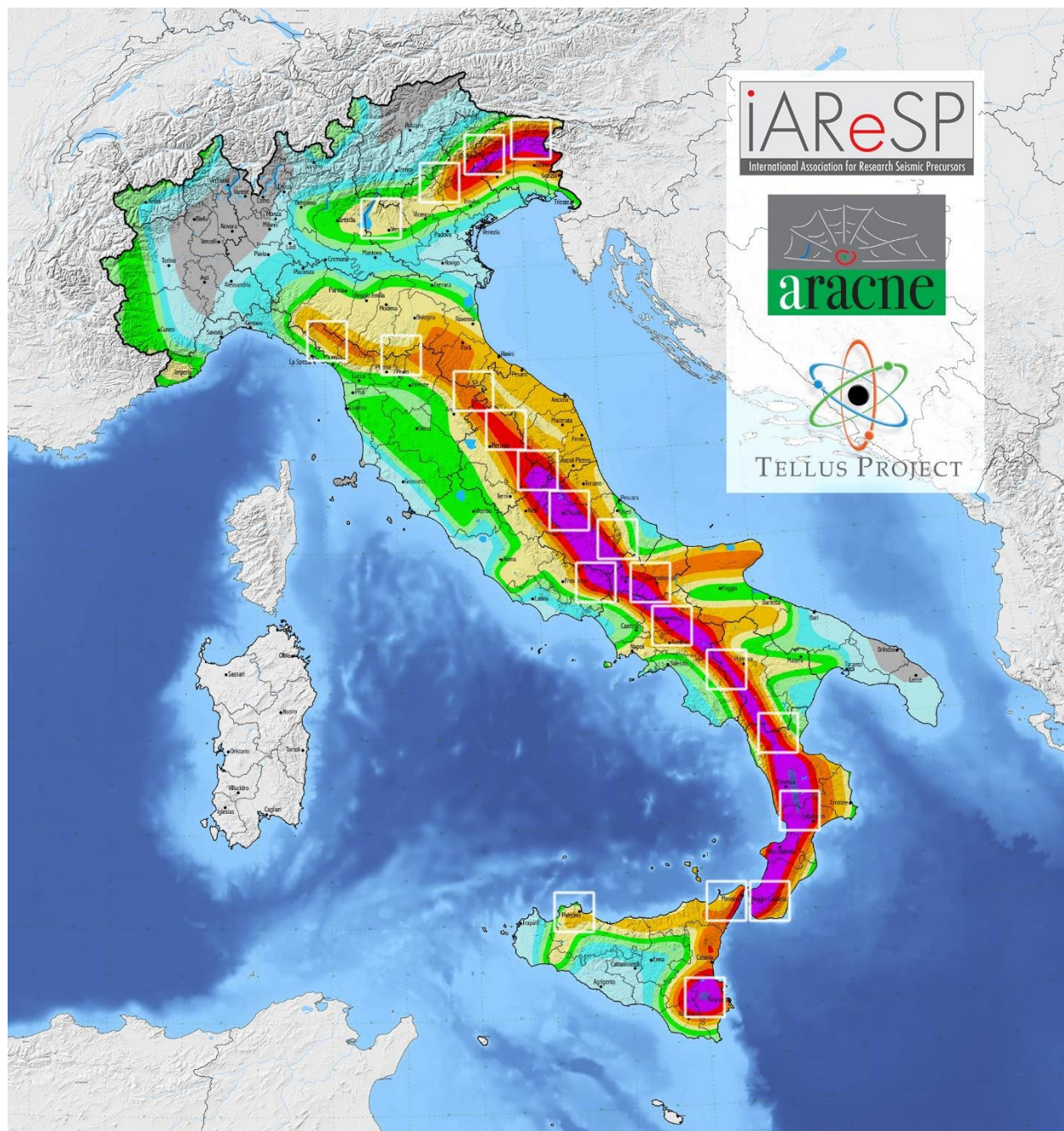
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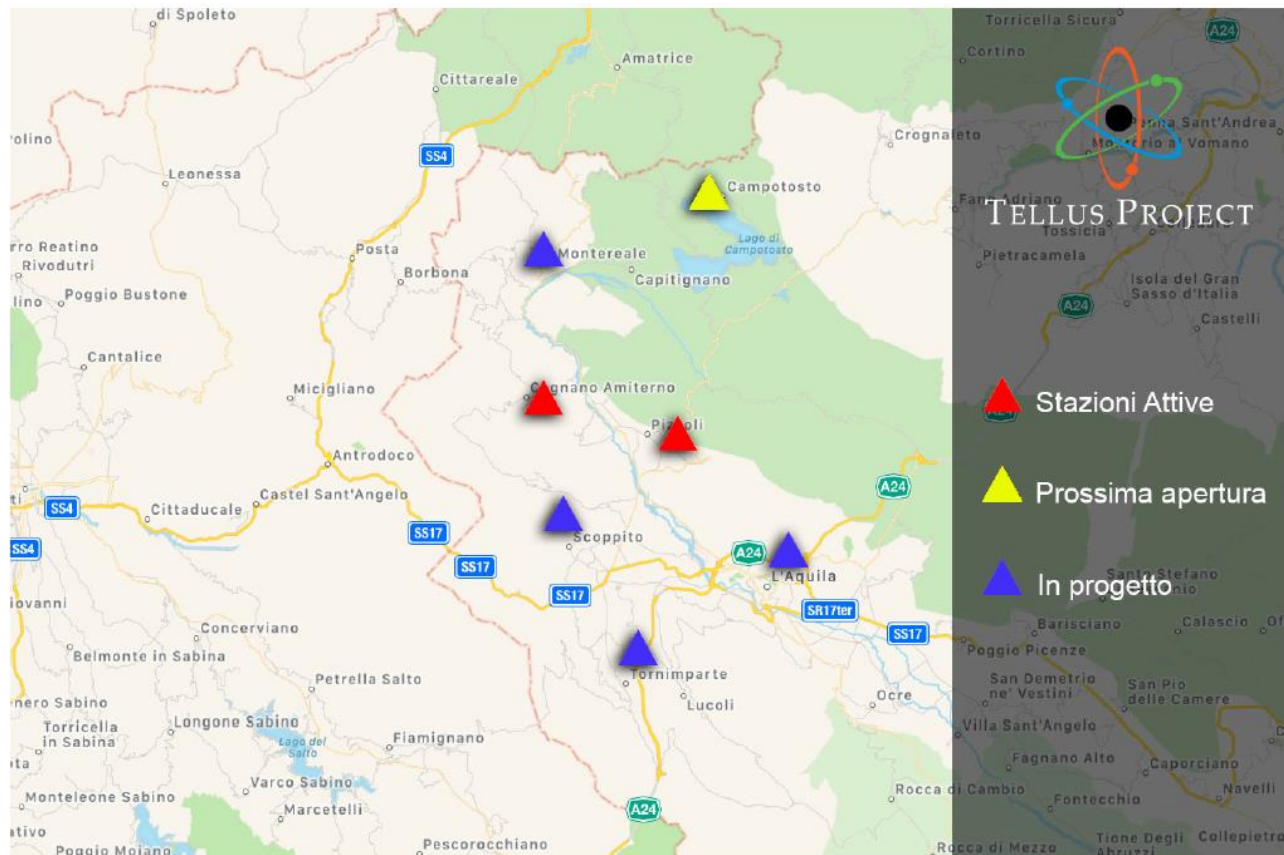Figure 1 – The Aracne Tellus Project

Figure 2 - Monitoring stations network. Tellus Project Stations. Red = Active, Yellow = Building, Blue = Planned.

Figure 3 - The Pizzoli Station (Tellus Project)

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Figure 4 - The Radon Monitoring Unit (Tellus Project)

Figure 5 - Triaxial sismograph (Tellus Project)

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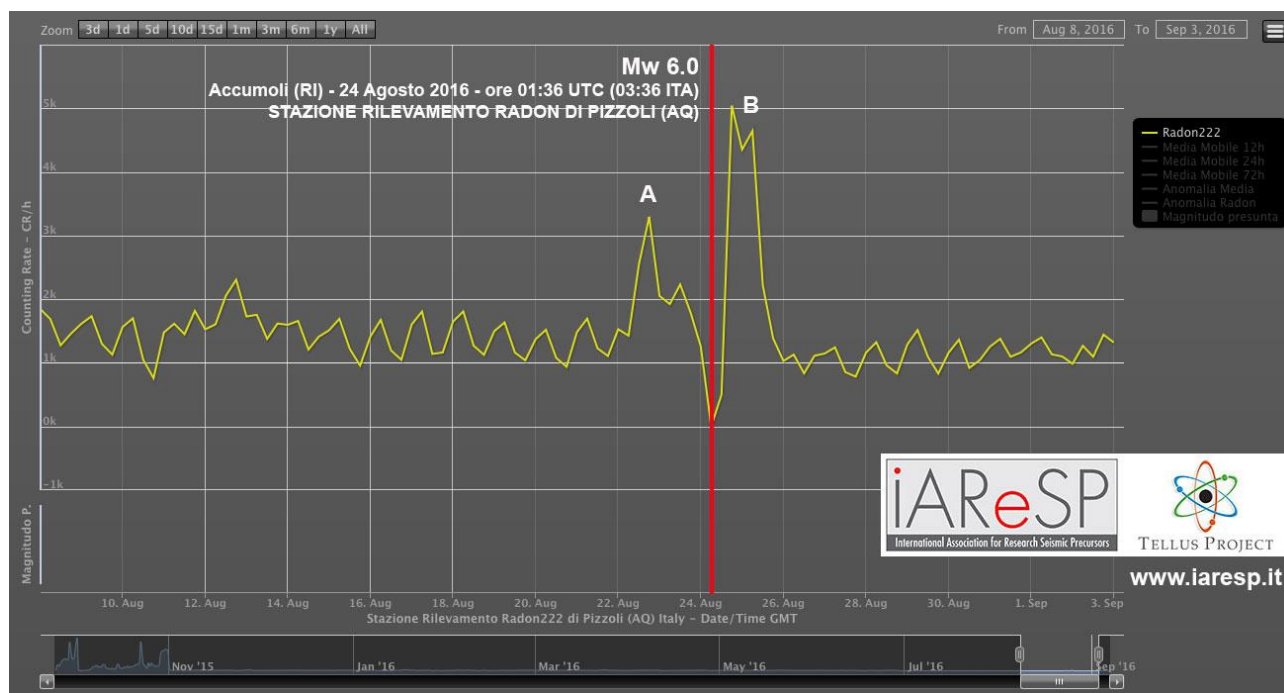
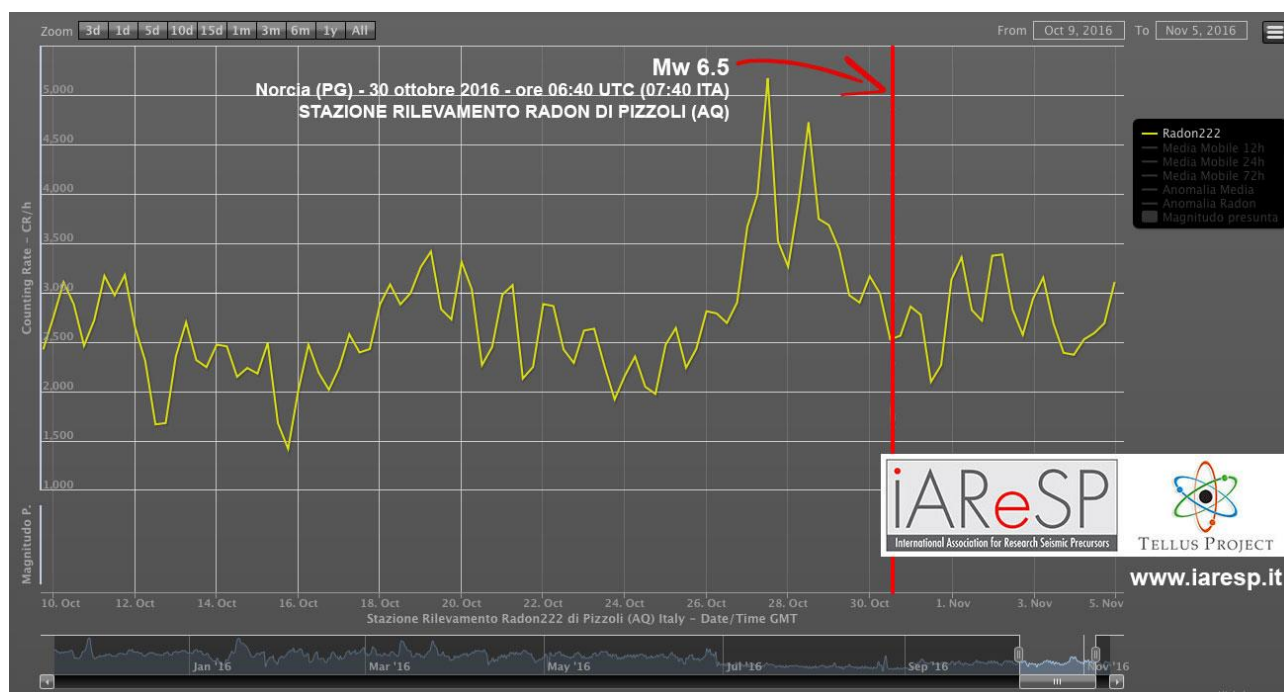Figure 6. August 2016. Major Earthquake in red, radon emissions in yellow. Pizzoli station.

Figure 7. October 2016. Major Earthquake in red, radon emissions in yellow. Pizzoli station.
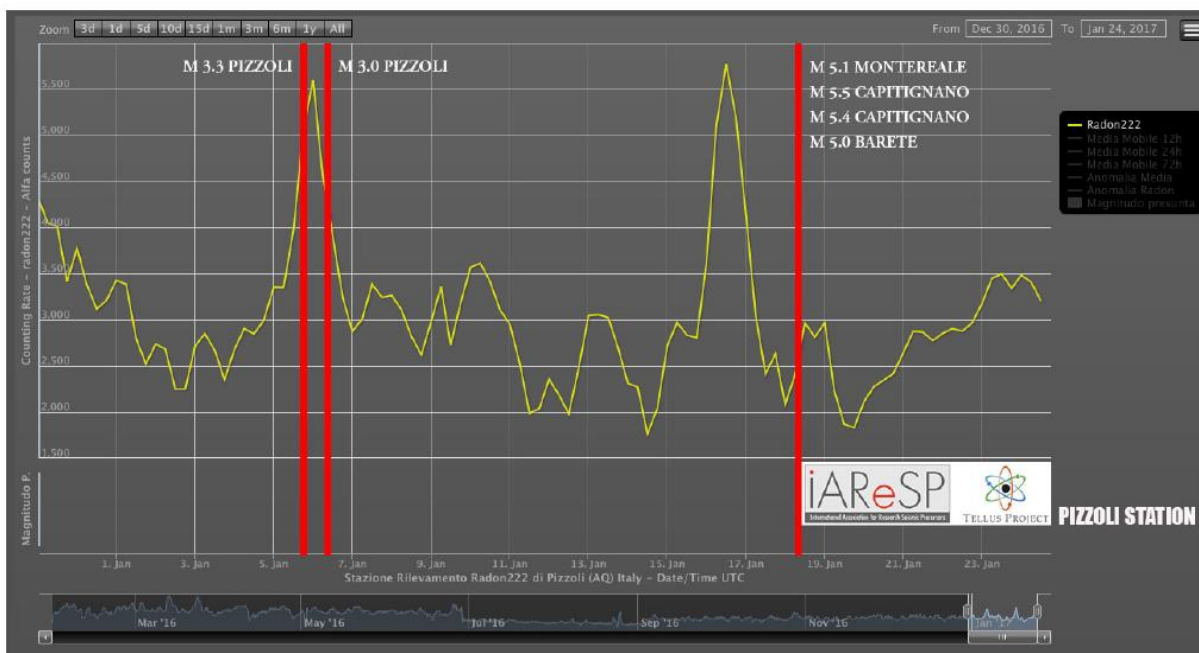
Figure 8. January 2017. Minor and major Earthquakes in red, radon emissions in yellow. Pizzoli station.