Extension of the radon monitoring network in seismic areas in Romania

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1. Abstract

The Romanian National Institute of Earth Physics (NIEP) developed a radon monitoring network mainly for Vrancea seismic area characterized by deep earthquakes. Few stations were relocated after a year of operation following inconclusive results regarding the relationship between radon and seismic activity. To the 5 stations that are in the Vrancea area (Bisoca, Nehoiu, Plostina, Sahastru and Lopatari) we added others positioned in areas with surface seismicity (Panciu, Râmnicu Vâlcea, Surlari and Mangalia). The last two are on the Intramoesica fault, which will be monitored in the future along with the Fagaraş - Câmpulung fault. Radon together with CO_2 - CO is monitored at Râmnicu Vâlcea within the SPEIGN project near a 40 m deep borehole in which the acceleration in three directions, temperature and humidity are recorded. The same project funded the monitoring of radon, CO_2 and CO in Mangalia, which is close to the Shabla seismic zone. The last significant earthquake in the Panciu area with ML = 5.7 R occurred on 22.11.2014. The area is seismically active, which justified the installation of a radon detector next to a radio receiver in the ULF band within the AFROS project. Within the same project, radon monitoring is performed at Surlari, following the activity of the Intramoesica fault. In this location we also measure CO_2, CO, air temperature and humidity. The first results show a normal radon activity in Panciu. The measurements in Surlari have higher values than those in Panciu, possibly due to the forest where the sensors are located. A special case is Mangalia where the data indicate more local pollution than the effects of tectonic activity. The source of these anomalies may be the local water treatment plant or the nearby shipyard. The purpose of expanding radon monitoring is to analyze the possibility of implementing a seismic event forecast. This can be done in a multidisciplinary approach. For this reason, in addition to radon, determinations of CO_2, CO, air ionization, magnetic field, inclinations, telluric currents, solar radiation, VLF - ULF radio waves, temperature in borehole, infrasound and acoustics are made.

2. Monitoring area, network stations, equipment

Monitoring area is presented in Fig. 1 next to the Romanian and Vrancea seismicity characterized by deep earthquakes (represented by blue color). The curvature of Carpathian mountains is characterized by many faults (Fig. 2) and intermediate earthquakes. In general, all monitoring stations are multidisciplinary to allow the correlation of data and the determination of the causes that generated an anomaly. Attempts were made to position the stations in the area of active seismic faults. It is unlikely that the deep Vrancea earthquakes are the source of radon variations, but in this area there are also a surface seismic activity (Fig. 3).

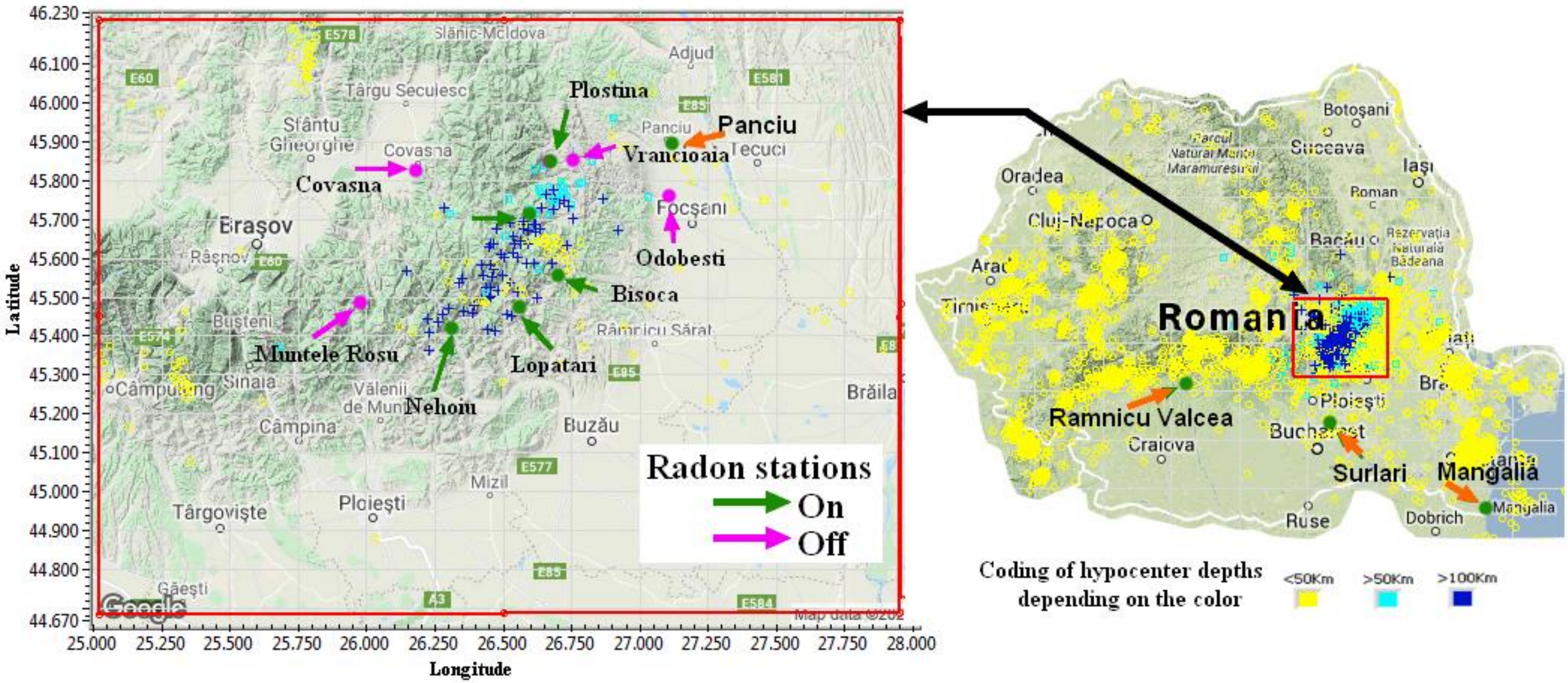
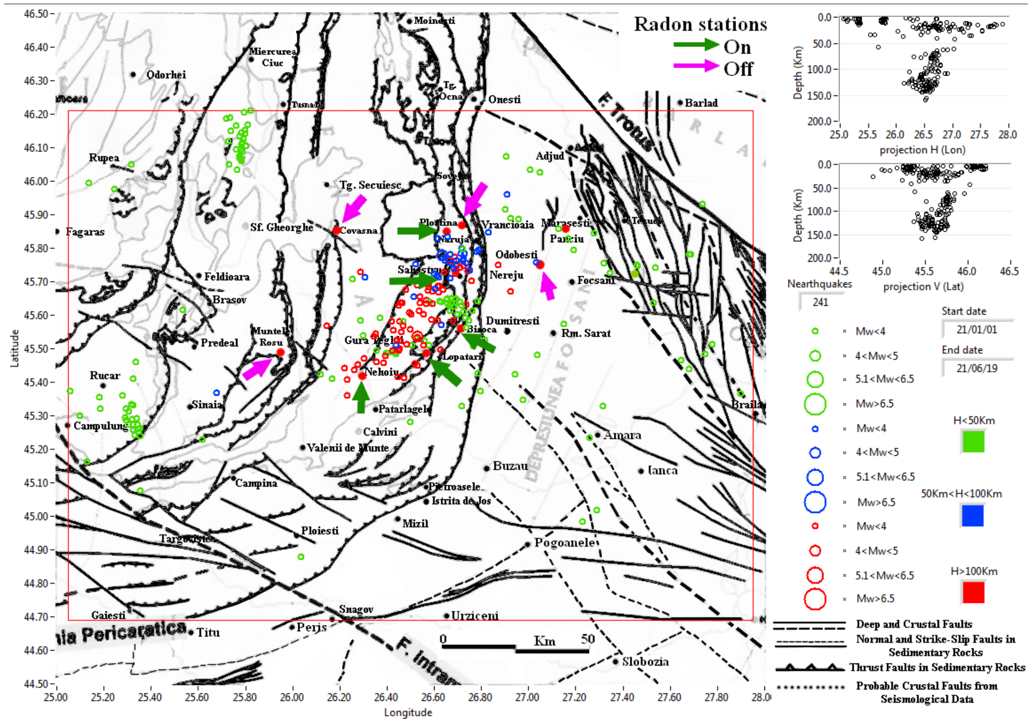
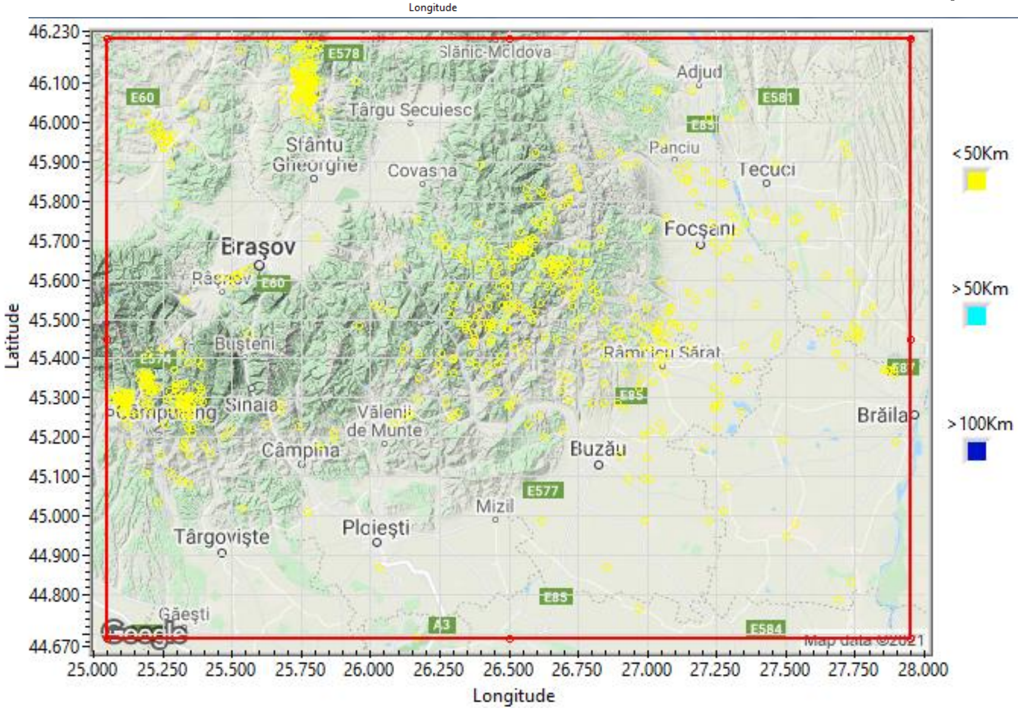


Fig 1. Romanian seismicity and radon monitoring stations.



Although the monitoring stations were positioned as close as possible to the resulting faults, the results were not conclusive in some cases. For this reason, the equipment has been reallocated. The most recent case is in Mangalia.

Fig. 2. Vrancea faults and seismicity, radon monitoring network [1].



Very large variations of radon and CO_2 are produced by activity in the area (most likely from the water treatment plant). In other cases, it was not possible to determine the causes that produced anomalies in the evolution of radon (Red Mountain Tunnel).

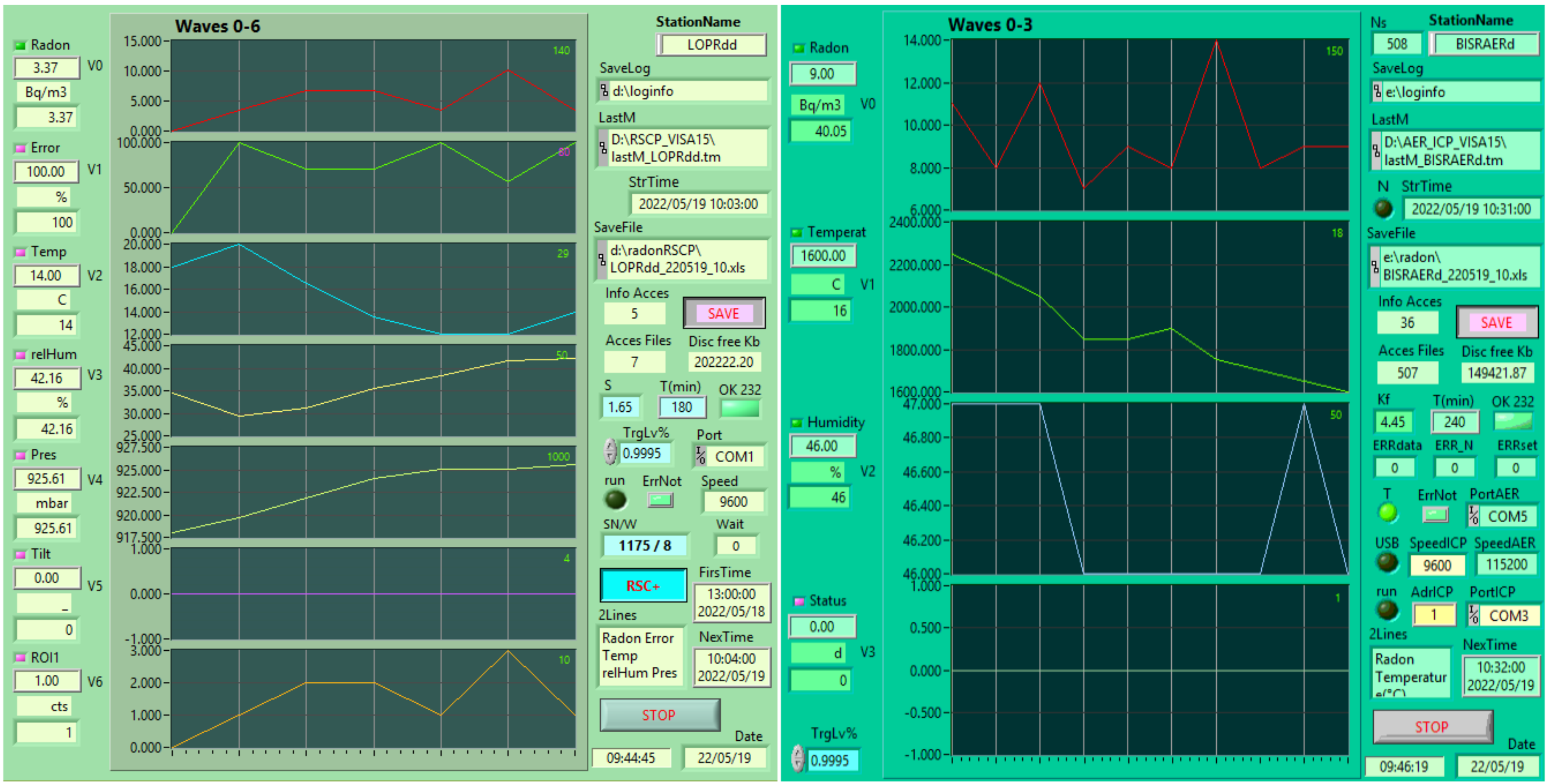
Fig. 3. Vrancea surface seismicity (H < 50 Km) 2020 – 2022 April.

The list of radon monitoring stations is presented in Table 1. Three types of equipment are used (AER + C - ALGADE, Radon Scout and Radon Scout Plus - SARAD). The first has the facility to automatically transmit data through the Sigfox service. Unfortunately, this service does not work properly in the Vrancea area. SARAD equipment does not have the facility to automatically transmit data being oriented to an offline analysis. It was necessary to carry out acquisition programs for these equipment to automatically transmit the information (radon, humidity, temperature, atmospheric pressure) to specialized servers on the acquisition of geophysical data.

Table 1. Radon network stations

Station	Location	Latitude N	Longitude E	Equipment
BISRAERdd	Bisoca	45.5481l	26.7099	AER +C
LOPRdd	Lopatari	45.4738	26.568	Radon Scout Plus
NEHRdd	Nehoiu	45.4272	26.2952	Radon Scout Plus
PLRdd2	Plostina	45.8512	26.6498	Radon Scout
SAHRdd	Sahastru	45.72664	26.68546	Radon Scout Plus
PANCdd	Panciu	45.8723	27.1477	Radon Scout Plus
RMGVdd	Ramnicu Valcea	45.10753	24.37708	Radon Scout Plus
SURLdd	Surlari	44.6777	26.2526	Radon Scout Plus
MNGdd	Mangalia	43.8168	28.5876	Radon Scout Plus

The acquisition software for Radon Scout Plus and AER+C equipment are presented in Fig. 4 (a, b). In the first case we use a serial interface (COM1, Fig. 4 a) and a binary protocol. The equipment characteristics are stored in its memory (sensibility, serial number, software version, sample time interval). The ROI1 parameter (region of interest, it is about nuclide separation by α spectroscopy, [3]) determines the Radon and the Error. For AER+C equipment we use the USB (converted in serial COM5, Fig. 4 b) interface because the Sigfox service does not work. In this case we found that the permanent use of the USB port introduces errors. For this reason this interface is only active when the data is read. A relay operated via a serial interface (COM3, Fig. 4 b) is used for this purpose.

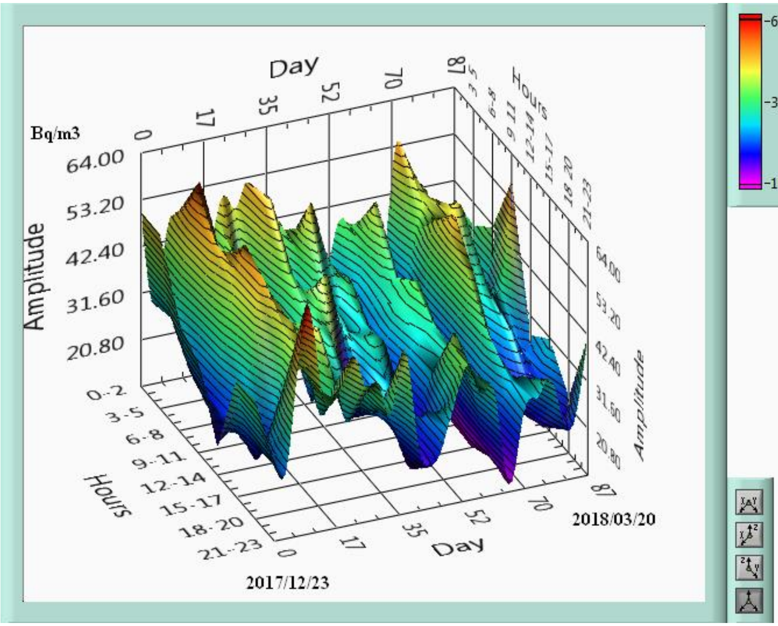


a b

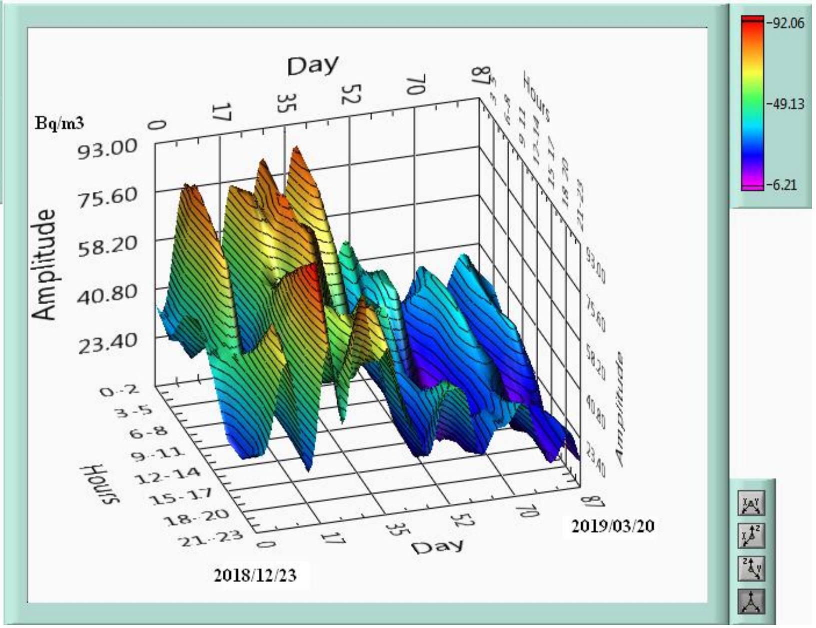
Fig. 4. Acquisition software for SARAD - Radon Scout Plus (a) and ALGADE - AER+C equipment (b).

3. Data Analysis and Methods

Data analysis and methods are described in [1] and [2]. The acquisition time was chosen so that the radon values of zero are minimal. This required a 3-hour sampling period for Radon Scout Plus equipment and a 4-hour sampling period for AER + C. The resulting files contain samples with a sampling period of 1 minute for compatibility with other data. This allows the determination of the values of several parameters at the same time and creates an independence of the data format from the sampling period of the equipment that can change depending on the evolution of radon. In order to be able to understand the evolution of radon in an area, a minimum monitoring period of one year is required, in which the daily and seasonal variations are analyzed. Fig. 5 is an example for Bisoca monitoring station.



(a)



(b)

Fig. 5. Radon evolution in Bisoca station, winter: (a) 2017; (b) 2018 [2].

A result of multidisciplinary monitoring (radon, solar radiation, magnetic field, atmospheric electrostatic field and lighting,CO_2, air ionization, Kp) is the implementation of an OEF (Operational Earthquake Forecasting) for a selected area (Vrancea in our case). The detection method for events is STA/LTA on integrated radon time series, Fig. 6 [1], [2]. We can only use detection and / or STA/LTA as the signal equivalent. The method also applies to CO_2 or air ionization, generally in the analysis of gas emissions. They are accumulated over time in a semi-open air volume that allows accumulation over a period of time. For this reason we integrate time series. Fig.7 is an example of radon data analysis [1].

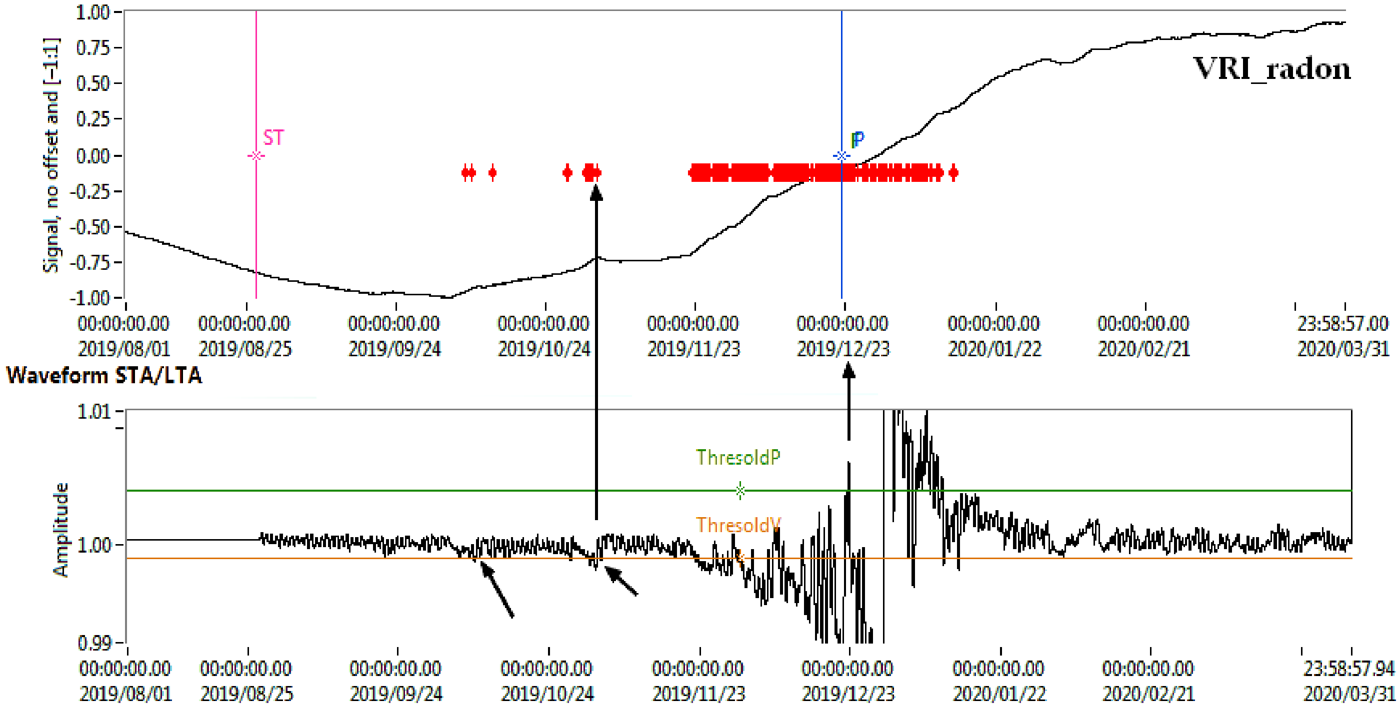


Fig. 6. Anomaly detection using short-time-average through long-time-average (STA/LTA) triggering algorithm [1].

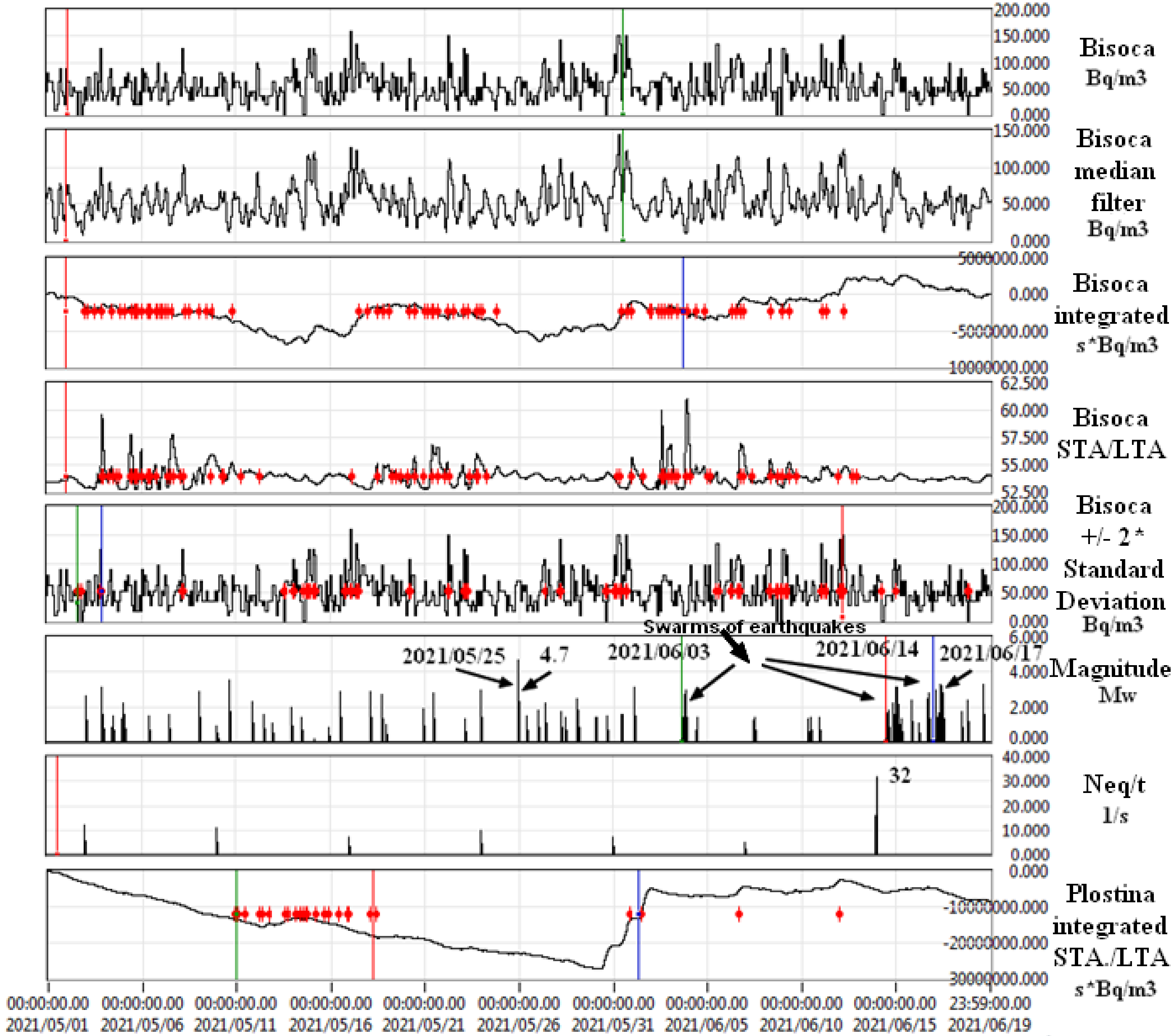


Fig. 7. Analysis of ^{222}Radon in Bisoca [1].

5. Conclusions

This research helps organizations specializing in emergencies not only with short-term earthquake forecasts but also with information on pollution and the effects of climate change that are becoming increasingly evident lately. The methods and solutions are general and can be applied anywhere by customizing them according to the specifics of the monitored area.

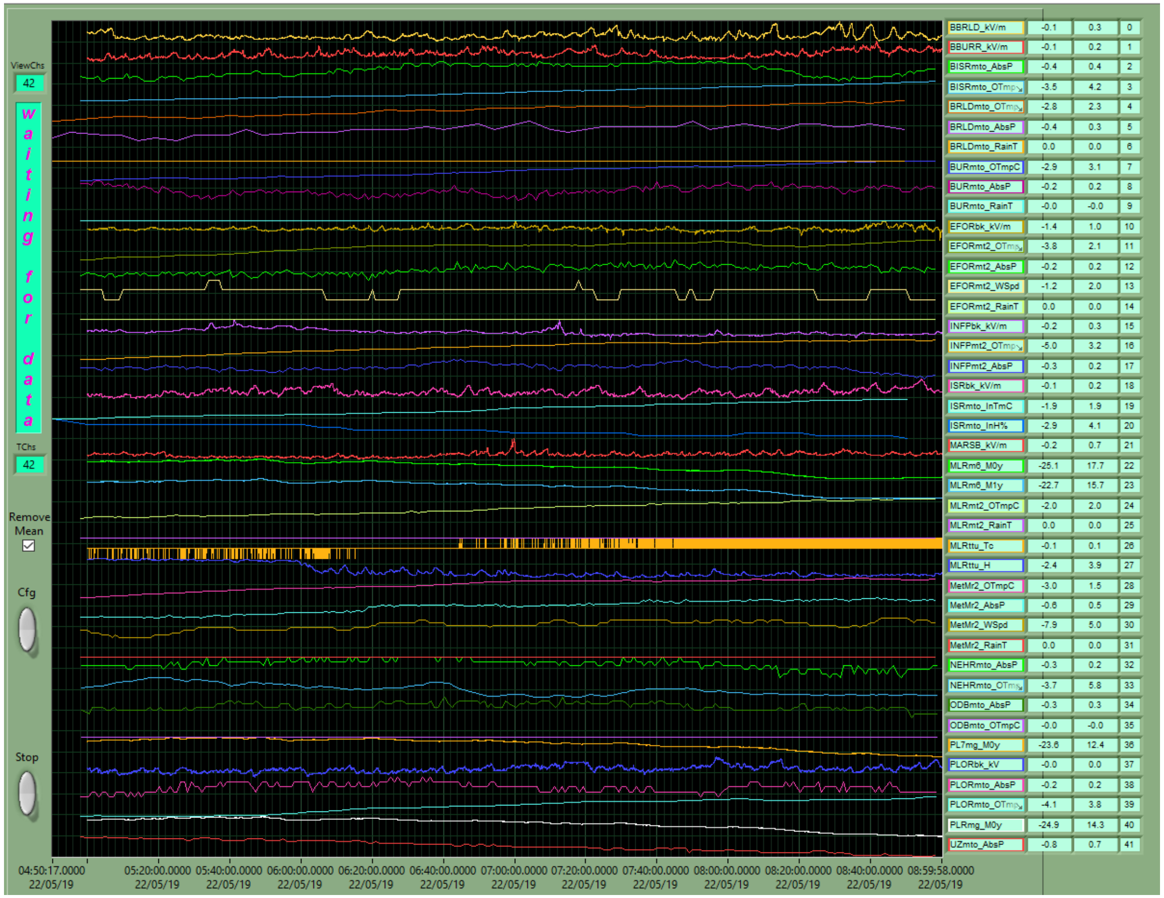


Fig. 8. Data server for multidisciplinary stations.

Radon is a seismic precursor but not enough. In the monitoring stations we also measure CO2, magnetic field, telluric field, atmospheric electrostatic field, direct and reflected solar radiation, radio waves in the ULF band (Fig. 8).

The main conclusion is that only a multidisciplinary approach allows the correlation of events and ensures a reliable forecast.

6. Selective References

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7. Acknowledgements

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Thank you !