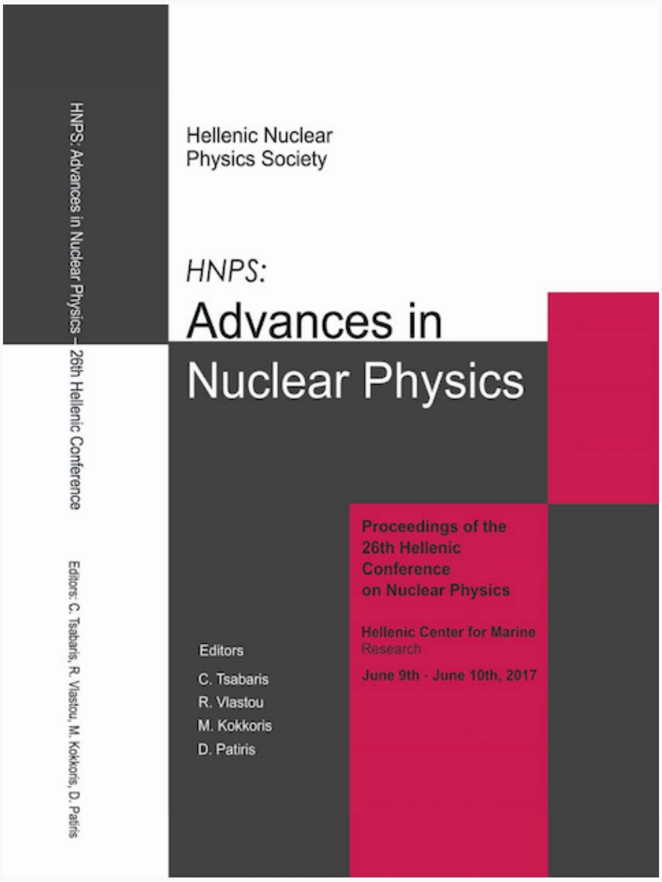
Annual Symposium of the Hellenic Nuclear Physics Society

Τόμ. 25 (2017)

HNPS2017



Temporal variation of soil radon emanation related to seismic activity

K. G. Ioannides, S. Alexandropoulou, C. A. Papachristodoulou, S. Bletsas, K. C. Stamoulis

doi: 10.12681/hnps.1992

Temporal variation of soil radon emanation related to seismic activity

K. Ioannides[1], S. Alexandropoulou[1,*], C. Papachristodoulou[1], S. Bletsas[1], K. Stamoulis[1]

[1]*Department of Physics, School of Sciences, University of Ioannina, 451 10 Ioannina, Greece*

Abstract In-soil radon concentrations, as well as soil temperature and atmospheric pressure, were continuously measured by a Barasol detector from November 3rd 2016 to April 8th 2017, in the area of Ioannina (Northwestern Greece), close to a recently activated fault system. During the study period, several seismic events were recorded in the vicinity of the monitoring site. To minimise the contribution of the atmospheric pressure to the in-soil radon fluctuations, a linear regression method has been used and the corrected radon concentrations were calculated. Radon anomalies in the region of ±2σ deviation from the average concentration have been identified and possible correlation with the recorded earthquakes has been investigated. The results obtained suggest anomalous radon increases preceding certain of the earthquake events, typically by a precursor time of a few days.

Keywords radon variation, soil gas, Barasol, earthquake precursor

---

INTRODUCTION

Radon is an alpha-emitting radioactive gas produced from uranium-radium found in rock grains or soil. Although radon emanation is influenced by meteorological parameters, such as temperature and atmospheric pressure, radon variation in soil gas can give evidence of tectonic disturbances in the Earth's crust [1]. The most frequent radon anomalies linked to seismic activities refer to large increases of in-soil radon concentrations before and during the seismic events recorded [2].

In the present study, concentrations of in-soil radon gas were continuously measured by a Barasol radon probe, from November 3rd 2016 to April 18th 2017. The monitoring site was in the region of Ioannina city, within 25 km from an active fault zone that gave rise to intense seismic swarms with magnitudes up to 5.3 in Richter scale, during October 2016. The quakes were distinctly felt by the population and the news was reported by the major national media. Seismic events, as well as meteorological parameters were also obtained during the monitoring period.

EXPERIMENTAL DETAILS

In-soil radon concentrations were monitored by a Barasol (MC2, ALGADE, France) detector probe, placed 1 m deep in the soil. The detector totalizes alpha emissions generated

---

* Corresponding author, email: xpapaxri@cc.uoi.gr

during pre-established time intervals of 60 min. A micro-processor is used to store the measured values, while readout is performed by a PC-compatible computer with associated software. The device also measures soil temperature and atmospheric pressure.

Earthquake data were collected from the Earthquake Data Base of the Geodynamic Institute of the Athens' National Observatory. Those events for which $M \geq 2.5$ and $RE \leq 1.5RD$ [3] have been considered, where M is the earthquake magnitude, RE (km) is the distance between the measurement site and the epicentre and RD (km) = $10^{0.43}M$ [4] is the effective radius of an area within which precursory phenomena may be manifested. The parameter $q = M^2 \times 100/RE$ was used to express the potential to detect a seismic event at a measurement site [5].

RESULTS AND DISCUSSION

The temporal variation of soil gas radon, soil temperature and barometric pressure are shown in Fig. 1. Radon fluctuations are observed, with amplitudes and durations that vary with time. Soil temperature gradually increases during the monitoring period; the diurnal variation is less than 0.5ºC and is unlikely to affect radon concentrations. However, the effect of the atmospheric pressure has been carefully considered in the deconvolution of radon variations. Daily averages have been calculated during selected time periods, free of seismic events, and a linear regression equation was applied (Fig. 1, inset). Following correction for the atmospheric pressure effect, the residual radon concentrations could possibly be linked to the seismic activity. The resulting data series is presented in Fig. 2, wherein the seismic events (e_i) listed in Table 1 are also indicated. Radon peaks appearing as a $\pm 2\sigma$ deviation from the average concentration value are considered as "anomalies" (a_i) – i.e. as precursors of a forthcoming earthquake.

Anomalous radon concentrations reaching 3 to 4 times the background values are detected on 7/11 (a_1), 8/11 (a_2) and 12/11 (a_3), about 3 to 7 days before the seismic swarm (e_1-e_{10}) that occurred from 10 to 19/11/16. A broad radon peak (a_4) extending from 5 to 10/12 is observed during the event e_{12} and about one week prior to earthquake e_{13}.

Date	M	RE (km)	q	ei	Date	M	RE (km)	q	ei
10/11/16, 1:00	3	20.1	44.78	e1	19/12/16 21:32	3.3	22.6	48.19	e13
11/11/16, 06:07	2.9	24.8	33.91	e2	31/12/16 19:20	2.8	19.2	40.83	e14
13/11/16, 22:52	2.9	22.2	37.88	e3	09/1/2017 18:04	2.7	19.1	38.2	e15
15/11/16, 19:21	3.2	22.2	46.13	e4	13/1/2017 17:24	2.9	18.7	45.0	e16
16/11/16, 00:27	3	21.6	41.67	e5	13/2/2017 19:08	3	24.8	36.3	e17
16/11/16, 11:41	3.8	19.8	72.93	e6	14/3/2017 23:51	3	17.8	50.6	e18
17/11/16, 19:54	3.2	22	46.65	e7	15/3/2017 1:22	2.8	20.1	39.0	e19
17/11/16, 20:23	3.3	22.6	48.19	e8	16/3/2017 3:00	3.3	18.7	58.2	e20
18/11/16, 17:41	3.2	22.9	44.72	e9	25/3/2017 19:53	3.5	39	31.4	e21
19/11/16, 04:29	3.1	19.8	48.54	e10	01/4/2017 23:46	3.4	22.5	51.4	e22
26/11/16, 03:43	3.5	26.7	45.88	e11	03/4/2017 19:32	3.1	24.4	39.4	e23
8/12/16, 22:37	2.8	22.2	35.32	e12					

Table 1. Seismic events recorded during the monitoring period 3/11/2016 – 18/4/2017.

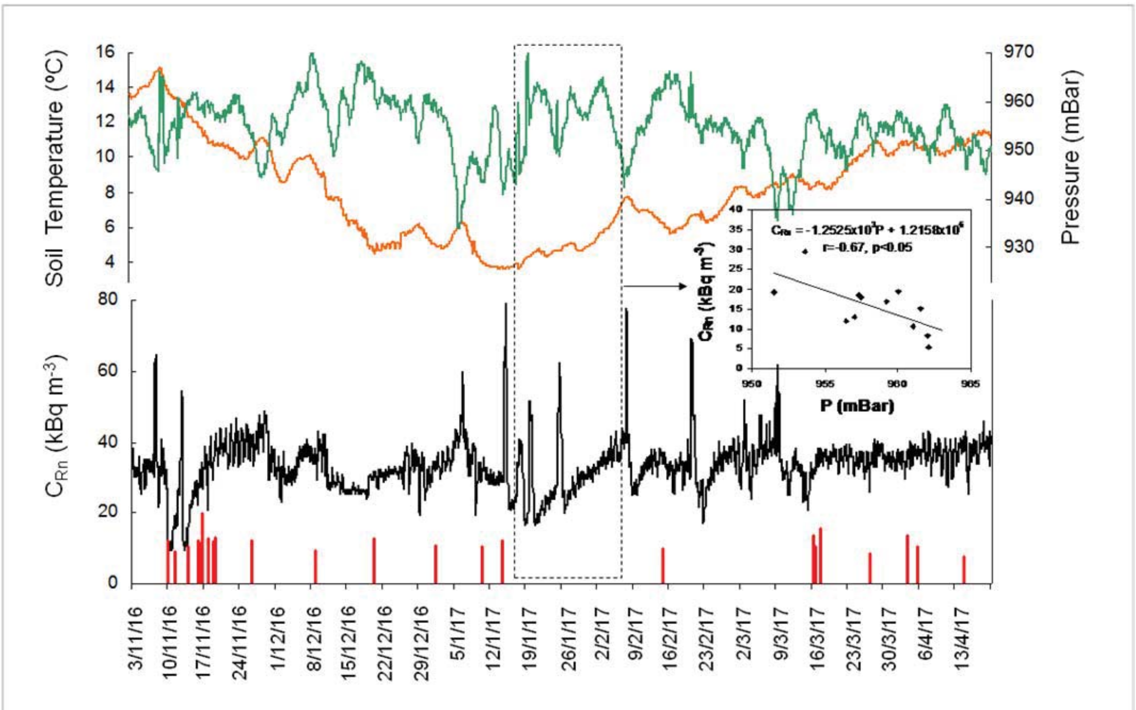


Fig. 1. Temporal fluctuation of soil radon concentration (C_{Rn}), soil temperature and atmospheric pressure. Seismic events are indicated by red lines, corresponding to their q-parameter (see text). Inset: The linear regression model applied to account for the effect of atmospheric pressure on radon variation.

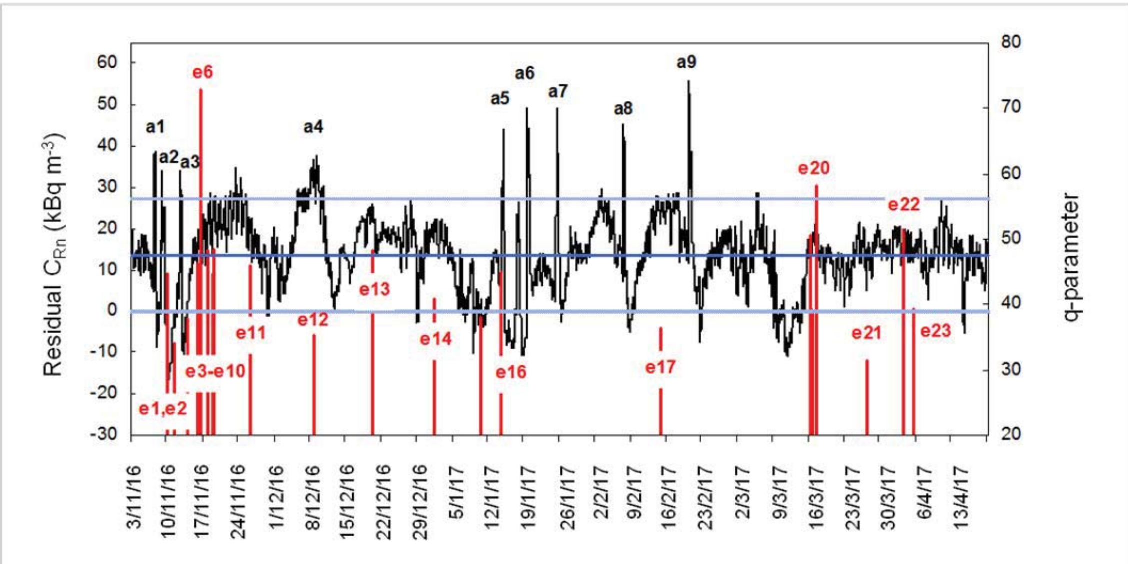


Fig. 2. Residual soil radon concentrations after correction for the atmospheric pressure effect. The average and ±2σ deviation values are shown in blue lines. The observed radon anomalies (a_i) are compared with earthquakes (e_i) from Table 1.

Pronounced anomalies with concentrations exceeding background values by a factor of 4 to 6 are evidenced on 14/1 (a_5), 19/1 (a_6), 24/1 (a_7), 6/2 (a_8) and 19/2 (a_9). It is not clear, however, whether these anomalies are linked to e_{15}, e_{16} and e_{17}. It is noted that the seismic events e_{18}-e_{20} occurred within less than a month from a_9. Anomalies in soil radon concentrations, registered a few weeks or months before many earthquakes have been reported in the literature [6].

CONCLUSIONS

In-soil radon concentrations, as well as soil temperature and atmospheric pressure were measured at a site close to a recently activated fault system in the region of Ioannina, NW Greece. The contribution of the atmospheric pressure to radon fluctuations has been minimized and radon anomalies have been determined according to the $\pm 2\sigma$ deviation criterion. Several seismic events were recorded close to the monitoring site, during the study period. Radon concentrations have shown anomalous increases preceding certain of the recorded earthquakes, typically by a precursor time of a few days. The results demonstrate that radon is a good indicator of earthquakes, but since the magnitude and duration of the anomalies, as well as the precursor time are highly variable, the need for long time series should be emphasized, to allow for false positives identification and to achieve a deterministic forecast.

References

[1] K. Wattananikorn, M. Kanaree, S. Wiboolsake, Radiat. Meas. 29, p. 593 (1998)
[2] A. Riggio, M. Santulin, Boll. Geofis. Teor. Appl. 56, p. 95 (2015)
[3] J. Vaupotič, A. Riggio, M. Santulin et al. Nukleonika 55, p. 507 (2010)
[4] I.P. Dobrovolsky, S.I. Zubkov, V.I. Miachkin, Pure Appl. Geophys. 117, p. 1025 (1979)
[5] I. Miklavčić, V. Radolić, B. Vuković et al. Appl. Radiat. Isot. 66, p. 1459 (2008)
[6] J. Planinić, V. Radolić, B. Vuković, NIMA 530, p. 568 (2004)