Physics and Chemistry of the Earth 85–86 (2015) 114–118

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Laboratory measurements on radon exposure effects on local environmental temperature: Implications for satellite TIR measurements

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ARTICLE INFO

Article history:
Received 9 December 2014
Received in revised form 2 March 2015
Accepted 23 March 2015
Available online 15 April 2015

Keywords:
radon
surface latent heat flux
thermal infrared radiance
earthquake precursors

ABSTRACT

Surface latent heat flux (SLHF) is proportional to the heat released by phase changes during solidification, evaporation or melting. Effects of SLHF on the earth's surface could be measured by satellite techniques capable of measuring thermal infrared radiation (TIR). Recent studies have found a possible correlation between SLHF and earthquakes, hence satellite techniques are widely used in research into the possible link between SLHF and earthquakes. Possible fluctuations in SLHF values during seismic periods have been attributed to different causes, such as the expulsion from the ground of greenhouse gases or because of radon. In particular, ionization processes due to radon decay could lead to changes in air temperature. Laboratory experiments have been carried out to highlight the possible role of radon in the thermal environmental conditions of a laboratory-controlled atmospheric volume.

1. Introduction

Anomalous increases in environmental temperature in concomitance with local earthquakes have been reported by many authors. Mil'kis (1986) analysed the strongest earthquakes ($6 < M < 8$) occurring in the past century in Turkmenistan, Uzbekistan, Tajikistan and Kyrgyzstan and reported that the monthly temperature was slightly higher than the average value calculated over decades of observations during months in which strong earthquakes occurred. Dey and Singh (2003) reported that Surface Latent Heat Flux, a parameter linked to environmental temperature, increased in concomitance with $6 < M < 7$ seismic events occurring in India, Taiwan and Mexico. Freund (2009) and Freund (2011) reported that possible ionization phenomena capable of affecting atmospheric temperature could be due to charge motions in high-grade metamorphic rocks and in igneous rocks. Pulinets et al. (2006) reported that two strong earthquakes ($6 < M < 7.6$) occurred in Mexico and California during anomalously warmer periods. Pulinets et al. (2006) reported that radon variations in the atmosphere are the primary source of possible ionization processes capable of inducing temperature variations due to latent heat changes of water aerosol. In particular, each alpha particle emitted by radon decay with the average energy $E_{alpha} = 6$ MeV can produce about 2.73×10^5 electron–ion pairs. The radon output in concomitance with crustal deformative processes that can accompany earthquakes can reach significant values and induce, in principle, ionization rates of about 7.6×10^3 - $cm^{-1}\ s^{-1}$ (Pulinets et al., 2006), capable of eventually increasing the environmental temperature. Experiments on atmospheric ionization by alpha-particles decay were carried out by Bricard et al. (1968) who injected thoron (an isotope of radon) in a controlled atmosphere tank while other devices capable of inducing ionization processes without radionuclides decay were described and discussed by Pulinets et al. (2006 and references therein). According to Pulinets and Boyarchuk (2004), the key factor for the origin of thermal anomalies is the process of formation of the ion clusters with water molecules. The increased radon emanation from active faults and cracks prior to earthquakes could be the primary source of air ionization and the water molecule attachment to the newly formed ions during condensation could lead to the excretion of the latent heat. In such a case the temperature increase should be accompanied by equivalent drop in absolute humidity. Satellite remote sensing measurements have demonstrated that significant thermal anomalies related to Thermal Infrared Radiance (TIR) variations have been observed in

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http://dx.doi.org/10.1016/j.pce.2015.03.007
1474-7065/

concomitance with seismic events over large areas and these evidenced the possibility to detect eventual precursory phenomena (Tramutoli et al., 2001; Tronin et al., 2004; Pulinets et al., 2006 and references therein). Tramutoli et al. (2013) listed and discussed alternative generation mechanisms capable of explaining, in principle, observed TIR anomalies. In order to better understand what is the heat amount possibly generated by radon interaction with the atmosphere a number of experiments were carried out in equipped laboratories.

2. Experimental methods and equipments

Experiments have been carried out following two different arrays.

The first experimental array (Fig. 1) was set up in the Laboratory of the Institute of Geological Sciences of the University of Wrocław and used for two experiments.

In particular, the following equipment and procedures were utilized during the first experiment carried out in Wroclaw.

The Flir ThermaCAM PM695 camera operated in the spectrum band 7.5–13 μm with thermal resolution of 0.01 °C.

The RadStar RS300-I Radon Detector/Monitor was adjusted at 1 h of resolution time. Radon after diffusion was about 50 Bq/m^3.

No thermal effect was observed so a more effective radon source was used. In particular, the following equipment and procedures were used during the second experiment carried out in Wroclaw.

(1) A radon source hosted in a radon generator (iron container of volume c.a. 0.025 m^3 with uranium minerals samples) was sealed upside down by gypsum plaster to a granite plate for 30 days to accumulate radon.
(2) Radon activity accumulated and concentration measured by a Kodak LR115 device placed inside the radon generator was 352,440 Bq/m^3.
(3) The radon generator was placed and opened inside a Styrofoam chamber of 1 × 0.5 × 0.5 m made up of styrofoam plates of 0.05 m thick.
(4) Necessary humidity was obtained by placing wet polyester sponges inside chamber.
(5) A RadStar RS300-I radon 222 Detector with one-hour resolution time was utilized.
(6) An Infrared camera Flir Therma CAM PM695 characterized by a thermal resolution of 0.01 °C was utilized.
(7) Working conditions were characterized by $T = 28.3$ °C and humidity = 85%.

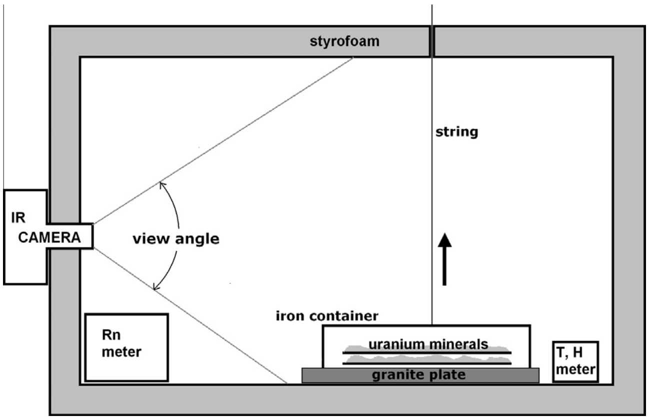

Fig. 1. Wrocław experiment chamber.

Starting radon activity concentration in the styrofoam chamber was measured by RadStar RS300-I radon 222 Detector in the time interval 15.00–16.00 was 207 Bq/m^3. After the opening of the radon generator at 16.45 the average value of radon activity in the Styrofoam chamber for the whole time interval of measurement 16.00–17.00 increased to the value of 392 Bq/m^3 and during the time interval 16.45–17.00 reached the value of 950 Bq/m^3. During following time interval 17.00–18.00 the measured average value was 706 Bq/m^3.

The second array was assembled in the Radon chamber of the Central Laboratory for Radiological Protection (CLOR) in Warsaw. A Radon chamber is equipment typically able to maintain a known radon concentration by pumping constant volumes of radon gas into a container. It is normally used for calibration of instruments, for precise measurements of radon in industrial devices, etc. The following equipment and procedures were utilized.

The radon generator is constituted by a Radium 226 Standard NIST solution.

Working conditions are characterized by $T = 20$ °C and humidity = 85%. The air-tight climatized NEMA ® chamber body (see also Stavarz et al., 2006) is characterized by walls made of 100 mm sandwich elements constituted by zinc, steel and plastic materials.

The inner sizes are 2.75 × 2.25 × 2.15 m while the volume is 13.2 m^3.

The chamber is equipped with an ante-room of 3.12 m^3 (1.50 × 1.04 × 2.00 m) with viewing window, manipulating gloves and a number of input ports which permit the injection of radon gas and aerosols, sampling inside and a system to remove radon outdoors after experiments.

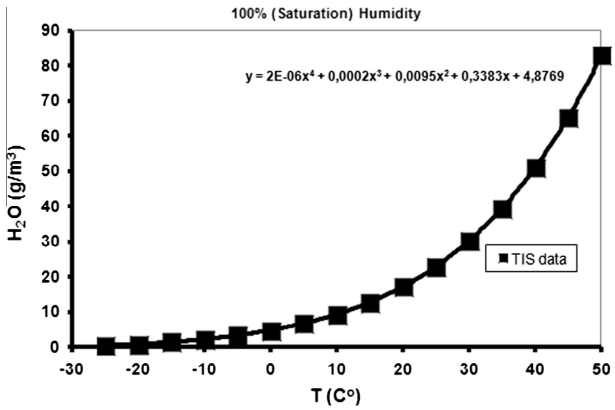

Fig. 2. Changes of 100% (Saturation) absolute humidity with temperature and calculated 4-th order polynomial regression line.

Table 1
Changes of 100% (Saturation) absolute humidity with temperature.

Temp (°C)	100% (saturation) humidity (g/m^3)
50	83
45	65.4
40	51.1
35	39.6
30	30.4
25	23
20	17.3
15	12.8
10	9.4
5	6.8
0	4.8
−5	3.4
−10	2.3
−15	1.6
−20	0.9
−25	0.6