Environmental Low Energy Gamma Rays Measurements in Brazilian Tropics Region During 2016

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Abstract: Low energy gamma radiation (0.2-10.0) MeV near the Earth’s surface has several origins. Primary and secondary cosmic radiations with interactions of very high energy protons (> 1 GeV) in terrestrial atmosphere are the main sources. The second most important source near the surface of the Earth and in the tropical and equatorial regions is the radon gas (Rn-222) that decays in alpha particles and gamma rays in this energy range. Also the telluric radionuclides $^{238}$U, $^{235}$U, $^{40}$K and $^{232}$Th in decays produce gamma radiation with different intensities at different locations on the surface of the Earth. Other sources less present are electrical discharges (lightning strikes) and man-made radioactive sources for medical, dental and industrial applications. In this work, it is shown that measurements of these components during all year 2016 are carried out at the ITA (Technological Institute of Aeronautics) campus in São José dos Campos, SP, Brazil and their possible correlations with atmospheric phenomena.

Key words: Gamma radiation, atmospheric phenomena, electric discharges, radon gas.

1. Introduction

In the ground level interface of the Earth’s atmosphere, ionizing radiation is mainly comprised of radon gas, the telluric radiation from the ground and the primary and secondary cosmic radiation produced in ground and low atmosphere [1]. However, it is difficult to separate over time the intensity of ionizing radiation emanating from each component as the energies overlap. The telluric radiation is constituted by $^{238}$U, $^{235}$U, $^{40}$K, $^{232}$Th chains, and it is constant in each specific region [2]. Radon gas Ra-220 and Rn-222 are measured by isotopes $^{214}$Pb, $^{214}$Po and $^{214}$Bi originating from the uranium decay in the earth’s crust [3, 4]. The primary cosmic radiation consisting mainly of galactic and extragalactic protons and from the sun with very high energy which interact with the Earth’s atmosphere produces the EAS (Extensive Air Showers) [5]. The efficiency of this interaction is maximal when it occurs at altitudes between 13 km and 17 km in the tropics forming secondary cosmic rays with muonics, hadronics and electromagnetic components that propagate to the Earth’s surface in the same region. These radiations cause health problems for the crew and passengers of civil and military aviation and are more intense present at the beginning of the stratosphere (13 to 17) km, called Pfotzer maximum.

However, this component contributes less to radiation concentration on the Earth’s surface. Another possible existing ionizing radiation source in the lower atmosphere of the Earth is produced by electrical discharges between clouds-earth ground; clouds-clouds and earth ground-clouds. X-rays, gamma rays, neutrons and beta particles are formed all the way of the lightning cone [6, 7]. Other ionizing radiation sources are those produced in industry, medical or dental clinics and hospitals, but these radiations are mostly controlled in small areas.

2. Material and Methods

To monitor the gamma radiation in range between 200 keV to 10.0 MeV, it has been used a portable
system detector composed of one Sodium Iodide scintillator activated with Thallium NaI(Tl). This crystal (3” x 3”) inches (diameter and high) wrapped in a thin cylinder of aluminum foil coupled with a PM (photomultiplier) with source power circuit in 1500 VDC and with data acquisition system provided by the company (Aware Electronics-Inc., USA) [8]. Detector and associated electronics were previously calibrated in ITA (Technological Institute of Aeronautics) laboratory using radioactive sources Cs-137, Sr-90 and Po-210. In terms of energy from emitted photons and particles: 1.17 MeV, 0.90 MeV and 5.4 MeV respectively [9]. The rainfall intensity in mm at each sampling minute was observed through a system (bascule/bucket) rain gauge and data logger acquisition developed in ITA according to the international recommendations. The data acquisition in terms of ionizing radiation and intensity of rainfall was performed using 1-minute time interval between each measurement. This detail contributes to verify possible correlations between variation of rain intensity, and local ionizing radiation. The set of devices were installed at a room 25 meters high from the ground where it was monitored gamma rays and all associated electronics [10]. The rain detector is placed on the outside on top of the room with electrical and electronic connection with cables connected in computers and data logger inside room. Fig. 1 shows the structure of the tower on the outside view, closed with controlled room temperature of 20 degrees Celsius.

3. Results and Discussion

The measures of environmental ionizing radiation were made at 25 meters high inside the room showed in tower of Fig. 1. The gamma-rays measures range from 0.200 MeV to 10.0 MeV for the period of December 18, 2015 to January 22, 2016, is shown in Fig. 2.

Fig. 3 shows measurements performed between 02/12/2016 and 03/23/2016. During this period, there were very few rainfall occurrences in the region, as indicated by the variations of gamma radiation recorded in this graph. Two strong/moderate rains stand out, and eight small weak showers or drizzles.

In the month of April between the days 16 and 25 the weather in the region was very dry and hot. This behavior of the local atmosphere is shown in the gamma radiation graph measured in the same period as illustrated in Fig. 4.
Due to strong heat between 25.0 and 35.0°C and low relative humidity of ~30%, gamma radiation predominates from radon gas (Rn-222). The perfect 1-day period visible in Figs. 4 and 5, perfectly reflects this behavior of the local atmosphere. This local thermodynamic equilibrium was disrupted with the abrupt arrival of a cold front on day 04/25 resulting in a drop in the intensity of radiation seen in Fig. 4. This low local atmosphere behavior in terms of gamma radiation measured was studied by making the FFT (fast fourier transform) [11], Fig. 5, in the data obtained and represented in the same Figs. 4 and 5. In the first days of May 2016, a small period of rainfall is highlighted, increasing the intensity of gamma radiation measured in the same period as shown in Fig. 6. It can be noted in this same figure the period without rain until May 30, 2016, where the variation of the intensity of the gamma radiation is almost not observed. Between May 25 and August 26, the presence of increased gamma radiation is observed in Fig. 7 which is shown at the beginning of June and at the end of August, coinciding with rainfall.
Fig. 5  Graph of the technique (FFT) showing the periods of 1 day and ½ day in the measurements indicated in Fig. 4 [11].

Fig. 6  Measurements of gamma radiation and rainfall highlighting correlation for the month of May 2016.

Fig. 7  Measures taken between 05/25 and 08/26 with heavy rainfall at the end of May and the end of August 2016.
During these days, there is a very small increase variation of the radiation in continuous way, but without presence of rains. Increasing heat and decreasing the relative humidity of the air or at the air/ground interface with arrivals of cold fronts causes this typical curve of the observed radiation in the period. Rainfall in the region at the beginning of May 2016 influenced the increase in gamma radiation shown in Fig. 7. Between 20,000 and 120,000 minutes there were no intense rains, but already at the end of August there were rains with (35 mm) of total intensity.

Fig. 8 shows the measurements of gamma radiation carried out in August/September 2016. There were no intense rains, but four weak or moderate rains. Sometime intervals in this period of measurements are observed with periodicities of 24 hours indicating dry and sunny days.

Fig. 9 shows the measurements of the gamma radiation and its variations for the months of October and November of 2016. During this period, two intense and five weak rains are indicated by the variation of the gamma radiation in the same period.
Fig. 9 highlights the measurements carried out between October and November 2016. There were 4 heavy rains, 5 weak or moderate rains in the region.

Fig. 10 shows the gamma radiation graph between November 14, 2016 and January 2, 2017.

This graph shows the existence of one heavy rainfall and seven weak rains in the observed period.

4. Conclusion

The uninterrupted measurements of gamma radiation every minute throughout 2016 clearly show the variation of rainfall in the region, even identifying its intensities. It is verified that in dry periods with low and constant relative humidity of the air as indicated in Fig. 4, the intensity of the radiation varies with the presence day/night with exact period of 1 day. It is stated that this perfect periodicity in the measured intensity of the gamma radiation is linked to higher and lower exhalation of the radon gas (Rn-222) due to the day/night temperature effect in the region. This periodicity is partially or totally destroyed with the presence of fog and rain and drizzle in the region. It can soon be said that the region of São José dos Campos has intense radon gas exhalation activity as measured by local ionizing radiation measurements throughout 2016.

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