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Dynamics in Times of Ionizing Radiation and Rainfalls in Tropical Region of Brazil

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Abstract

Low energy gamma rays and rainfalls were monitored each minute in the region around São José dos Campos, (23^{0}:10`S, $45^{0}$:53`W) in Brazil, from March 7th to June 28th in 2017. In this period, it was possible to see the dynamic process that occurs between the presence of ionizing radiation (gamma rays) of low energy and the variation of rain intensity in (mm) / min in the same region. During this period, 12 major peaks of radiation intensity corresponding to 12 rains of high and low intensities were observed. This positive rainfall / radiation correlation is very noticeable in the tropical region of Brazil, which is certainly due to the presence of the decay of 238U uranium into radium 226Ra and arriving at the 222Rn radon with α emission particles and low energy gamma radiation. Therefore, the rain interferes in the presence of the local exhalation of the radon gas, causing the washing of this gas in the low atmosphere, increasing the intensity of radiation measured momentarily in that location. This work shows this dynamic measured in this interval in the year 2017, where there was rainy and dry weather in the place.

Keywords: Gamma Ray, Ionizing radiation, Rainfall analysis, tropical regions

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Contents

1. Introduction

In the ground level interface of the Earth's surface, ionizing radiation is mainly comprised of radon gas, the telluric radiation from the ground and the primary and secondary cosmic ray radiation. 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 composed of ^{238}U, ^{235}U, ^{40}K, ^{232}Th chains and is constant for each region [1]. Radon gas comes from the ^{238}U decay of the Earth's crust [2] to Ra-226 and Rn-222 arriving in isotopes ^{214}Pb, ^{214}Po and ^{214}Bi giving α and gamma radiation. The primary cosmic radiation mainly consists of galactic and extragalactic protons from the Sun with very high energy, which interact on the Earth's atmosphere producing the EAS (Extensive Air Showers) [3]. The efficiency of this interaction is maximal when it occurs at altitudes between 15 and 17 km in the tropics, forming secondary cosmic rays with muonic, mesonic, and neutronic components that propagate to the Earth's surface in the region [4]. These radiations cause health problems for the crew and passengers of civil aviation and are present at the beginning of the stratosphere called maximum Pfotzer. 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 and clouds-clouds. X-rays, gamma rays, neutrons and beta particles are formed all the way of the lightning cone [5]. Other ionizing radiation sources are those produced in medical, dental clinics and hospitals, but these radiations are mostly controlled in small areas.

2. Materials and Methods

The gamma ray detector for the energy interval of 200 keV to 10.0 MeV consists of a scintillating crystal of sodium iodide 3 inches high by 3 inches in diameter (3" x 3"), doped with thallium. This crystal is coupled directly to a photomultiplier (PM), which registers the pulses coming from the scintillator and with amplification and an analog-to-digital converter that is registered by a computer [6]. This experimental set is seen in Figure 1 located in a room inside a tower 25 meters high in relation to the ground. In that tower and with all radiation detectors and meteorological apparatus is running the project Atmosrad – Ionizing radiation in low atmosphere – since 2009. This project have grants each year from ITA and National Brazilian Research Council (CNPq).

Figure-1. View of the gamma scintillator with associated electronics and computer
Source: Project Atmosrad 2017

The scintillator coupled with a photomultiplier is wrapped in a thin layer of aluminum to make it portable. The set (scintillator + associated electronics + data acquisition) depends only on a laptop with fully charged battery to measure radiation up to 10 hours straight. However, for series of longer measurements, electrical grid or photovoltaic energy is used. The scintillator and associated electronics were calibrated in terms of energy and intensity of counts per minute at the ITA experimental physics teaching laboratory using radioactive sources and a spectrum analyzer of counts versus energy in the interval of 0,2 to 10 MeV (Millions of eléctron Volts) [7, 8].

3. Results and Discussions

Measurements were performed between March 7th, 2017 to June 28th, 2017 at the same location shown in Figure 1, at the 25-meters high IAE tower [7]. The interval between each measurement was set at 1 minute. Therefore, it was possible to verify periods of rain and the dynamic of ionizing radiation in the region. Figure 2 shows, during this period, 12 rains shown by the peaks of radiation increase, caused by these rains.

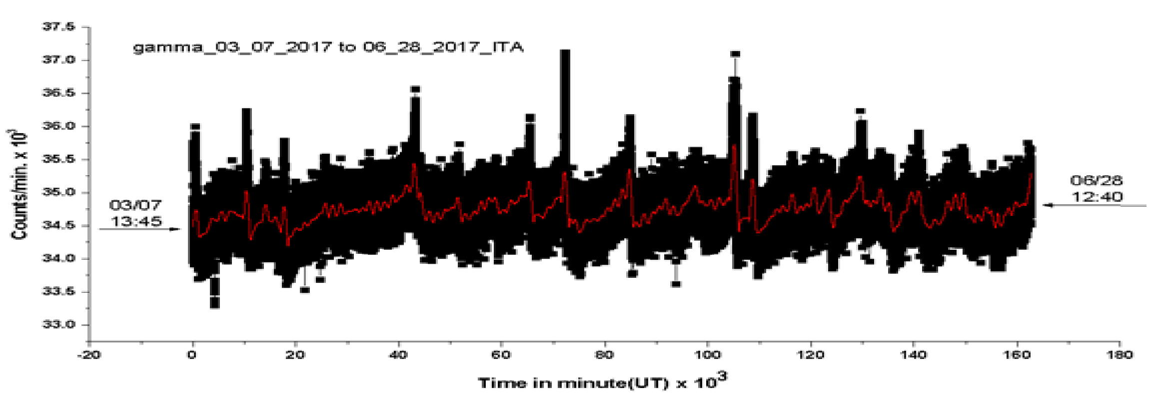

Figure-2. Measurements of gamma radiation in the interval of 0.2 to 10.0 MeV (Millions of electron Volts), each minute between March 7th and June 28th of 2017.
Source: Project Atmosrad 2017

Examining Figure 2, there is moderate rainfall between 43 to 43.5 x 10^3 minutes from the beginning of the monitoring of the radiation series. The expansion of the graph in this region shows the detail of the occurrence of rainfall via measurement of ionizing radiation (gamma rays) in this range, as shown by Figure 3.

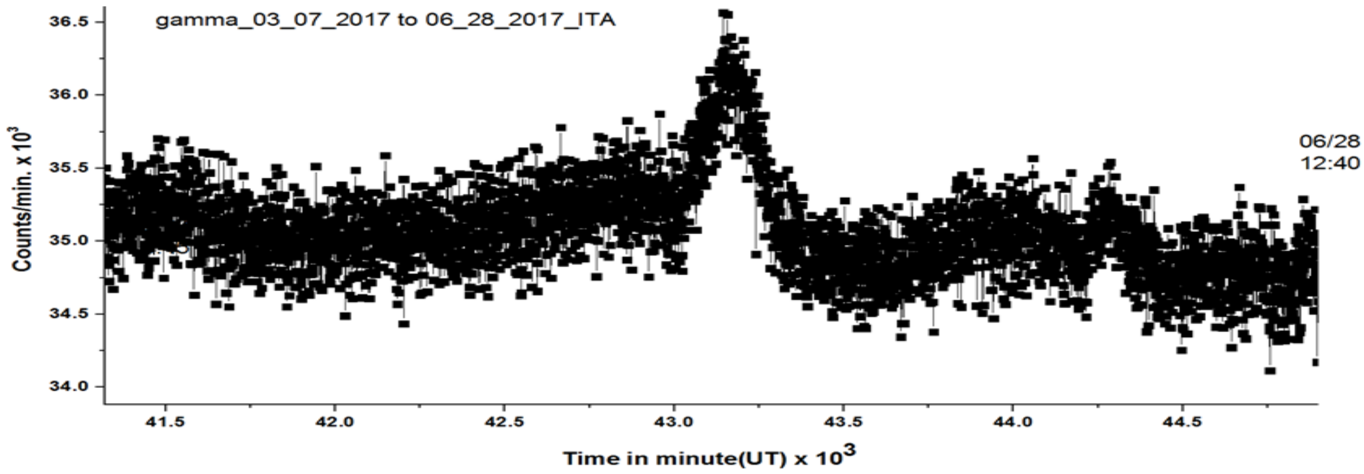

Figure-3. Monitoring of rainfall through gamma radiation in the interval between 43 to 43.5 x 10^3 minutes after the start of the measurements.
Source: Project Atmosrad 2017

Note this monitoring of radiation in Figure 4 shows a zoom close to the interval of 72000 minutes after the start of the measurements, where a cold front passes through the region culminating in an intense rain caused by this cold front. During five days, there was a small increase of local gamma radiation, leading to an intense rain at the end of these five days. This established meteorological dynamic is widely observed in the region in this period of time between five and seven days provoking rains and cloud coverings less or more intense. The transformation between dose of radiation µSv/h is related to Bq/m3 of the radon gas through the gamma formula [8]: $(\mu Gy/h) = 0.3857 + 0.000866\ Radon(Bq/m^3)$, so if it is measured a dose in time the amount of radon gas in Bq/m³ can be estimated.

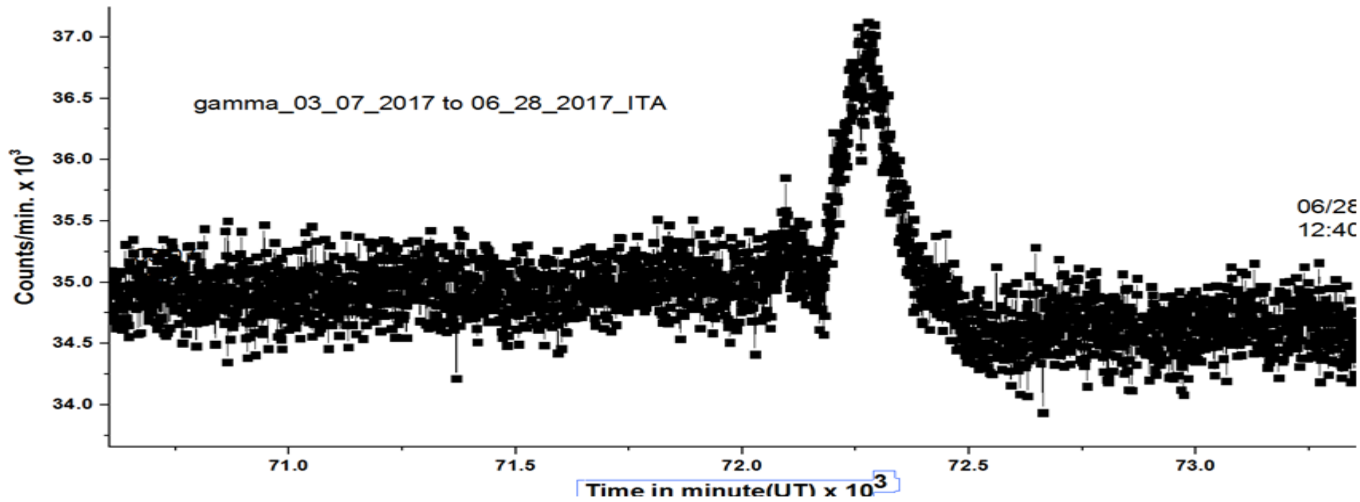

Figure-4. Interval of radiation monitoring in which there was rain between 72.0 to 72.5 x 10^3 minutes.
Source: Project Atmosrad 2017

During the period of 129.5 to 130.5 x 10^3 minutes, there were intermittent rains varying in intensity, see Figure 5.

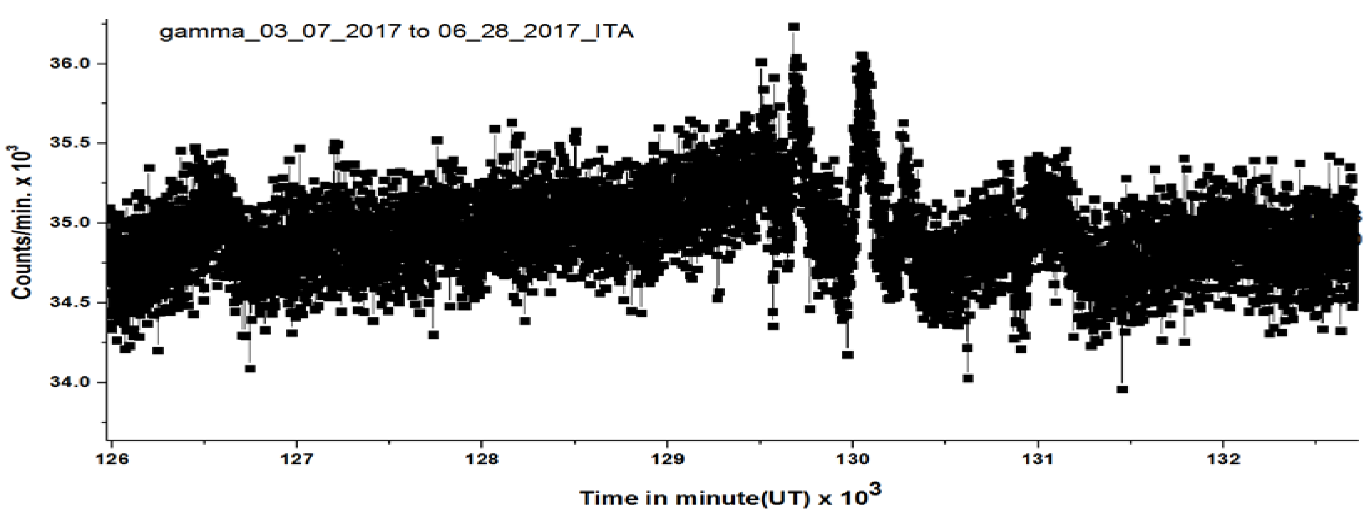

Figure-5. Intermittent rains varying in intensity, between 129.5 to 130.5 x 10^3 minutes.
Source: Project Atmosrad 2017

Another moderate rainfall that altered the intensity of measured gamma radiation can be observed at ~ 141 x 10^3 minutes after the start of monitoring, as shown in Figure 6. Before this rain, the local temperature rose to 30^0 degrees Celsius in the day before the rain due to the arrival of a cold front coming from Southern Brazil.

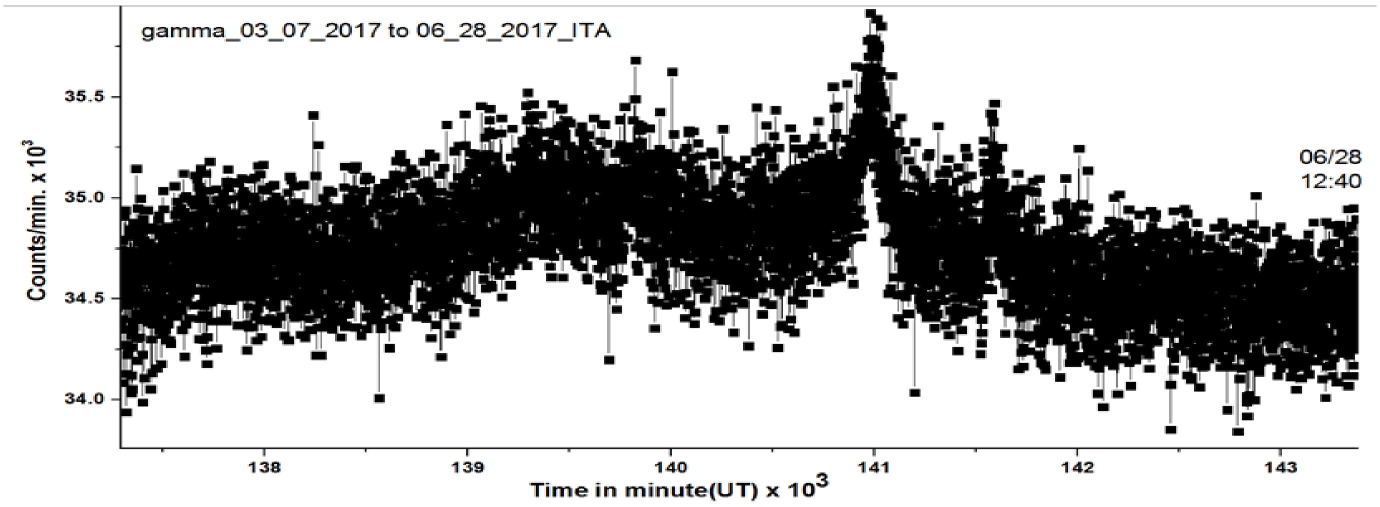

Figure-6. Moderate rainfall in the time of ~ 141,000 minutes of monitoring.

Source: Project Atmosrad 2017

Analyzing the dynamics of gamma radiation, measured from minute to minute as a function of time, at a fixed location, one can also observe the dynamics of the variation of rainfall occurring in the same place. Figure 7 shows the rainfall spectrum as a function of time measured in the same period and in the same place always with a one-minute interval between each measurement performed.

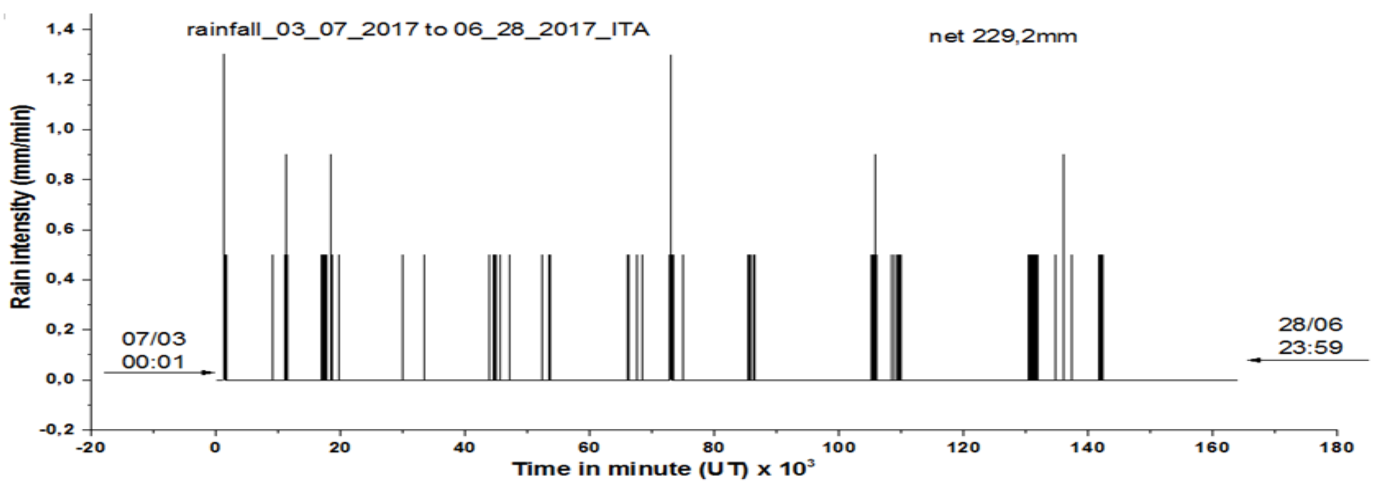

Figure-7. Spectrum as a function of time of rains occurred every minute between March 7th and June 28th of 2017.

Source: Project Atmosrad 2017

It is noted that the time around 43 x 10^3 minutes in Figure 7 corresponds to a moderate rain, observed in Figure 3, of radiation. Between 72 to 73 x 10^3 minutes, there is an intense rain, shown in Figure 7, corresponding to the increase of radiation seen in Figure 4. Figure 7 (intensity of rainfall in the period) can be carefully correlated with Figure 2 (intensity of gamma radiation in the period). Therefore, in the tropical region of Brazil due to the exhalation of radon gas it is possible to correlate intensity of radiation measured with local rainfall intensity presence.

4. Conclusion

In this work, using a simple gamma ray detector in the energy interval of 0.2 to 10.0 MeV, it was possible to correlate radiation measurements with rainfall measurements of the region carried out in the period of March 7th to June 28th of 2017.

This positive rainfall / radiation correlation is very noticeable in the tropical region of Brazil which is certainly due to the presence of the decay of the Uranium ^{238}U into Radium ^{226}Ra and decaying into Radon gas ^{222}Rn with the emission of **α** particles and low energy gamma radiation. Having calibrated between water intensity and the intensity of gamma radiation at this location, it is possible to measure the intensity of rainfall by monitoring the gamma radiation in the region. Another work is being done in order to show this calibration with tests carried out in the ITA laboratory [9].

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