Dynamics of low energy gamma rays near ground level during July to September 2017, in São José dos Campos, SP, Brazil.

Abstract

The variation of the gamma radiation intensity range between 200 keV to 10.0 MeV was measured, in the period from June 28 to September 25 of 2017. These measurements were taken 25 meters above ground level in a tower in São José dos Campos, SP, Brazil. It was used one-minute interval from each points of measurements. During this period there were weak and moderate rains with net intensity of 27 mm. The variation in temperature during this period was between 15°C and 32°C, reproducing a desert-like climate. By monitoring the gamma radiation it was possible to observe the arrival of cold fronts from Southern Brazil and the (day/night) cycles due to the greater or lesser amount of radon gas present in the region. The main features of this work indicates dynamics of gamma radiation in a simple way the variation of meteorological parameters in that location, which is very important for environmental studies.

Keywords: Gamma Radiation, Meteorological Parameters, Rainfalls

1. Introduction

At the (ground / air) interface of Earth's surface, the ionizing radiation is composed mainly of radon gas, the telluric radiation of the soil and the radiation of the primary and secondary cosmic rays. However, it is difficult to separate over time the intensity of the ionizing radiation emanating from each component as the energies overlap. The telluric radiation is given by ^{238}U, ^{235}U, ^{40}K, ^{232}Th and is constant for each region [1]. The radon gas that comes from the disintegration of ^{238}U of Earth's crust [2] into Ra-226 to Rn-222 arriving at the isotopes ^{214}Pb, ^{214}Po and ^{214}Bi giving alpha and gamma radiation. The primary cosmic radiation consists mainly of galactic and extragalactic protons and from the Sun with very high energy that interacts with Earth's atmosphere producing the EAS (Extensive Air Showers) [3]. The efficiency of this interaction is maximum when it occurs at altitudes between 15 and 17 km in the tropics, which form secondary cosmic rays with muonic, mesonic, and neutronic components that reach the Earth's surface in the region [4]. These radiations can cause health problems for the crew and passengers of civil/military aviation in this altitude that are present at the beginning of the stratosphere called Pfotzer maximum. However, this component contributes less to the concentration of radiation on the Earth's surface. Another possible source of ionizing radiation in the Earth's lower atmosphere is produced by electrical discharges between cloud-earth, earth-cloud and cloud-cloud. X-rays, gamma rays, neutrons and beta particles are all formed by the lightning cone [5]. Other sources of ionizing radiation are those produced in industry, medical, dental clinics and hospitals, but these radiations are mainly controlled in small areas.

2. Materials and Methods

The gamma ray detector for the energy range of 200 keV to 10.0 MeV consists of a 3-inch-by-3-inch-diameter and high sodium iodide scintillation crystal (3” x 3”), doped with thallium. This crystal is directly coupled to a photomultiplier (PM), which registers the pulses coming from the scintillator and with amplification and an analog digital converter (ADC) these digitized signals are recorded by a computer [6]. Detector was in a closed room and the air exchange was ensured during the measurements the experimental set (Figure 1) is located in the inner room of a tower (23°12'45.0"S 45°52'00.3"W), 25 meters high in relation to the ground.

Figure-1. View of the gamma scintillator with associated electronics and computer.
Source: Project Atmosrad 2017 [9]

The scintillator coupled to photomultiplier is wrapped in a thin layer of aluminum to make it portable. Scintillator and associated electronics were calibrated in terms of energy and counting intensity per minute, at the laboratory of experimental teaching physics of ITA (Technological Institute of Aeronautics), using radioactive sources and a spectral analyzer of counts versus energy in the range of 0.2 to 10 MeV (Million electron Volt), [7,8].

3. Results and Discussions

Gamma radiation measurements were carried out during the period of June 28 to September 25 of 2017, in the inner room above the tower, seen in Figure 2 below. During the interval described above, on the roof of the tower was the rain gauge that reported the intensity of rains in (mm / min).

Figure-2. Exterior view of the tower with the room 25 meters above the ground level.
Source: Project Atmosrad 2017 [9]

Figure 3 shows the measured gamma radiation intensity between June 28 to September 25 of 2017, with uninterrupted monitoring minute by minute during this net time.

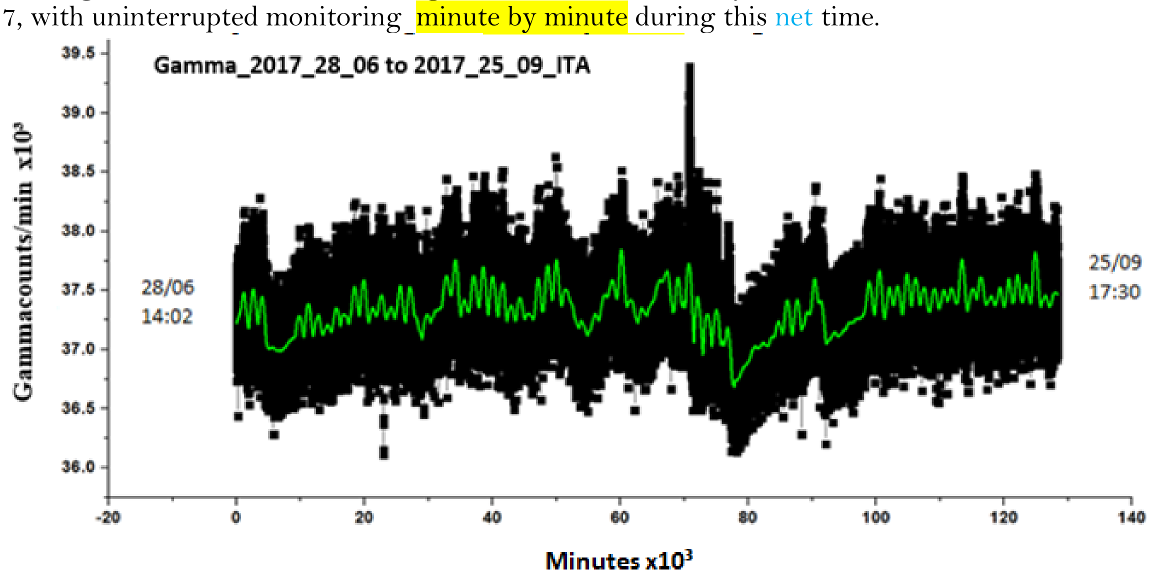

Figure-3. Monitoring of gamma radiation between the start time and 130 x 10^3 minutes after.
Source: Project Atmosrad 2017 [9]

The smooth tool was used to transform data from minutes to days as seen on the green line. Analyzing the dynamics of the radiation measurements, there are 4 large variations occurring in the whole period analyzed. Between the beginning of monitoring and close to 70 x 10^3 minutes, the mean intensity of the measured radiation was 37.5 x 10^3 (counts / minute). In this period it was possible see small variations what indicate passages of cold fronts without rain. See this dynamic in the expanded period in Figure 4, taken from the graph in Figure 3.

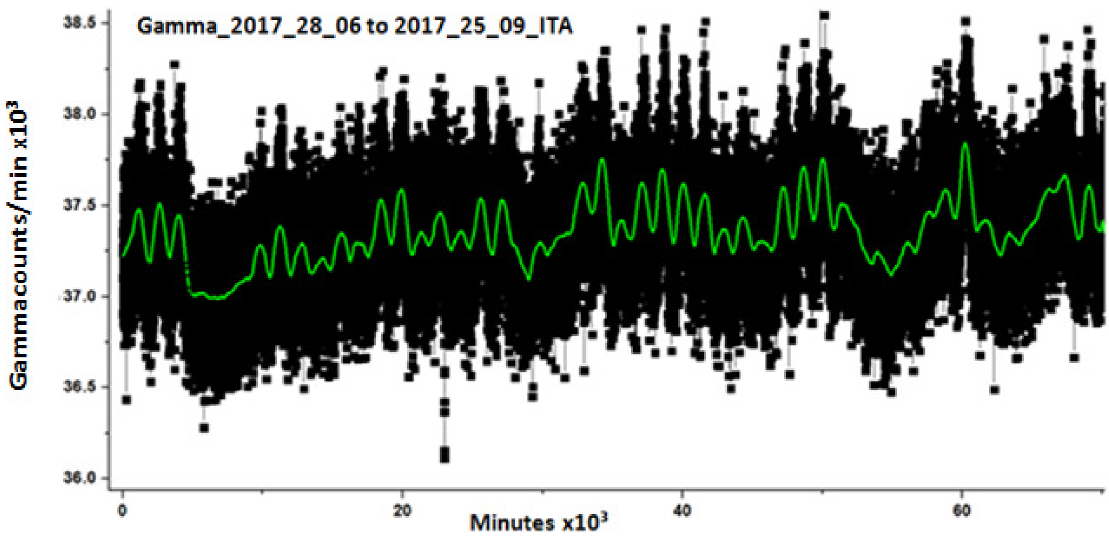

Figure-4. Monitoring of gamma radiation between the start time and 70 x 10^3 minutes after.
Source: Project Atmosrad 2017 [9]

Figure 5 shows the radiation monitoring between 70 to 80 x 10^3 minutes after the start of the measures. It was a rainy week with intensities varying according to Figure 5.

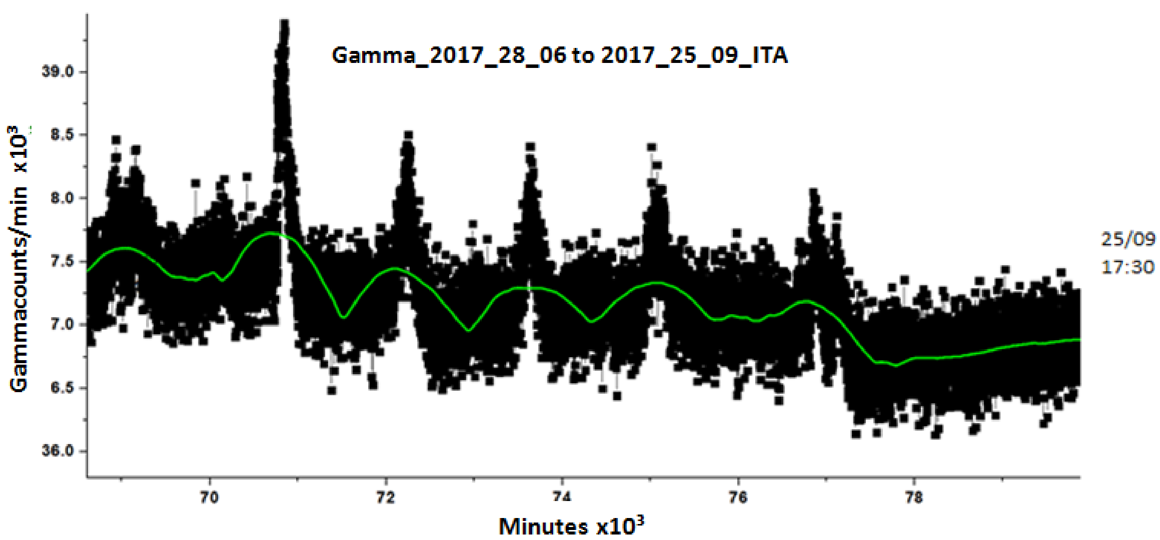

Figure-5. Monitoring of gamma radiation between 70 X 10^3 and 80 x 10^3 minutes after.
Source: Project Atmosrad 2017 [9]

In the beginning between 70 and 71 x 10^3 minutes there was intense rain, where the level of radiation count reached the order of 40 x 10^3 (counts / min). On the other days there were always less intense rains as shown by the radiation peaks caused by the rains. In Figure 6, taken during the measurement time of 80 to 100 x 10^3 minutes, there are variations in the dynamics of the radiation with passages of two cold fronts in the region, but without causing rains. However, the terrestrial surface was wet and with very little exhalation of radon gas. The arrival of the front causes an increase of the radiation due to the accumulation of radon gas that arrives with the cold front.

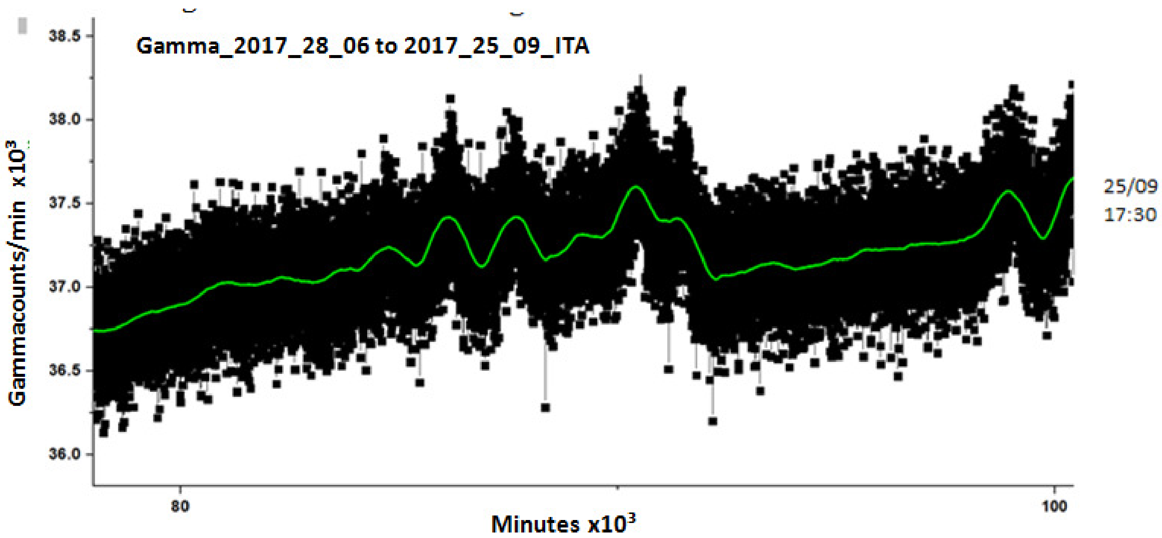

Figure-6. Monitoring of gamma radiation between 80 x 10^3 and 100 x 10^3 minutes after.
Source: Project Atmosrad 2017 [9]

In Figure 7, the gamma radiation intensity between the times of 100 to 130 x 10^3 minutes with average intensity of 37.3 x 10^3 (counts / min), undergoes an influence of soil in the region that was very dry and high pressure that was 970 mbar when local background value is 940 mbar. This occurs in the afternoon where the temperature varied between 20 to 30 °C and the night between 12 to 20 °C. This dynamics in temperature during this period facilitates greater and lesser exhalation of the radon gas, as shown in the figure 7 bellow with cycles of exactly 24 hours. The two largest radiation peaks, shown in Figure 7, are caused by heavy fog in the morning of those days.

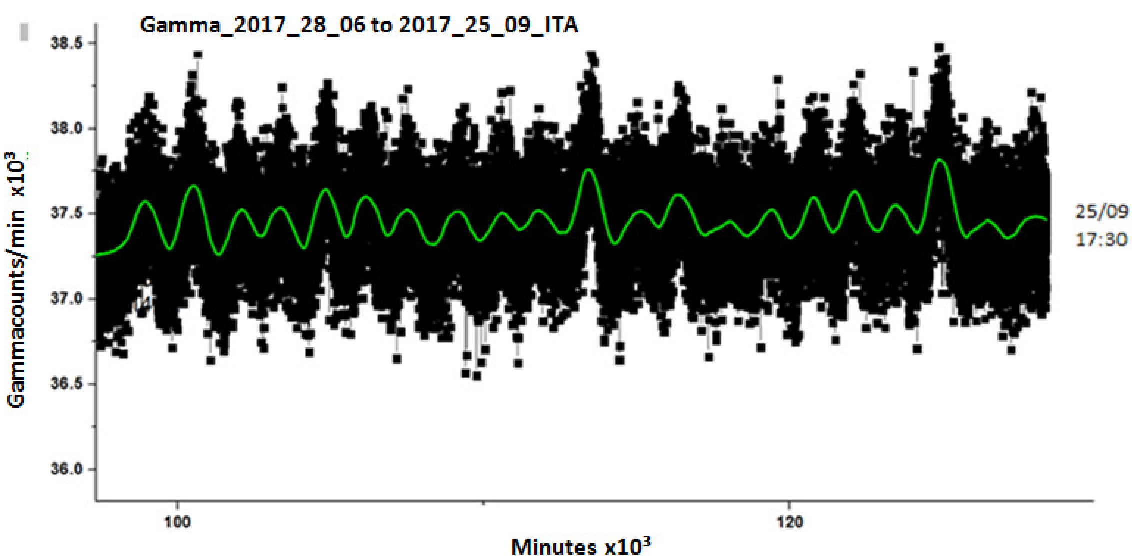

Figure-7. Monitoring of gamma radiation between 100 x 10^3 and 130 x 10^3 minutes.
Source: Project Atmosrad 2017 [9]

Figure 8 shows the rainfall spectrum in (mm / min), varying in time. During the whole period, only 27 mm of rain accumulated in the region in the course of a week.

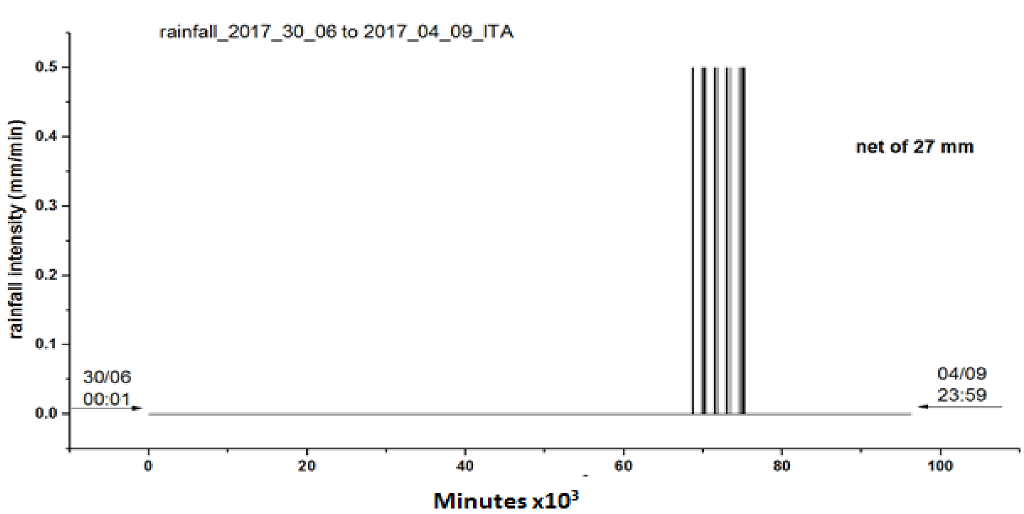

Figure-8. Spectrum in the time of the rains that occurred in the region during this period of measurements.
Source: Project Atmosrad 2017 [9]

The mean value for the period above mentioned historical give net of rain near 170 mm.

4. Conclusion

In the period of June and September of 2017, the intensity of rains was monitored every minute and in the same place and at the same time the intensity of low energy gamma rays was also measured. The analysis shows that during one single week of moderate and light rains, there was a noticeable increase in the intensity of gamma rays. The net rainfall in the period measured was 27 mm scattered in time. Figure 3 shows clearly the difference caused by the rains in the measurement of gamma rays. Also in this work, the perfect oscillation of the gamma rays (day / night) in the dry period is evidenced, without clouds, fog or lightning. This oscillation is caused by the exhalation of radon gas (Rn-222) in the region and is larger during the local solar zenith time with dry soil. The periodicity is partially or totally destroyed with the presence of fog, continuous rain and drizzle in the region.

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