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Correlation between cloud cover and gamma rays at ground level in São José dos Campos, SP

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Mauro Angelo Alves
Technological Institute of Aeronautics, SP.

Inácio Malmonge Martin
Technological Institute of Aeronautics, SP.

ABSTRACT

Simultaneous measurements made with a one-minute sampling interval of cloud cover at three height levels (250 - 2000 m, 2000 - 6000 m and 6000 - 8000 m) and gamma radiation counts obtained at ground level were carried out in May and June 2014. Results show that there is a degree of correlation between cloud cover and radiation counts. This correlation can be caused by the variation of the local amount of radon-222 gas, or by the production of radiation due to the acceleration of electrons originating from cosmic rays by electric fields inside clouds.

1 INTRODUCTION

The environment is exposed to ionizing radiation produced by various sources in nature. The main sources of natural radiation are cosmic rays and the decay of radioactive isotopes present in the Earth's crust (uranium-238, thorium-232, potassium-40) and in the air (radon-222). Often referred to as natural background radiation, radiation from these natural sources varies around the world according to factors such as altitude, latitude, local geology, weather phenomena, and geophysical events. The influence of cosmic rays on environmental radiation is already well known. Studies on the subject have been conducted since the early twentieth century, and Victor Hess won the Nobel Prize in Physics in 1936 for the discovery of cosmic rays. McCarthy & Parks (1984, 1985) recorded X-ray production associated with tropical storms with detectors installed on stratospheric balloons and aircraft. Fishman et al. (1994) first described the production of gamma rays by electrical discharges in the upper atmosphere. Moore et al. (2001) used NaI(Tl) scintillators located in high mountains to detect gamma-ray flashes associated with the occurrence of lightning. Gurevich et al. (1992) suggest that energetic photons are produced from the collision of relativistic electrons with atoms in the air and the release of energy in the form of radiation (bremsstrahlung). In addition to X-rays and gamma rays, there is solid evidence that neutrons are also produced by electrical discharges. Shah et al. (1985) first described the observation of neutron production by atmospheric electrical discharges. This type of phenomenon has been, for example, observed in observatories located at sea level or at low altitude (Kuzhevsky, 2004; Martin & Alves, 2010) and on mountaintops (Chubenko et al., 2008). Variations in the flux of thermal neutrons may also be related to seismic phenomena; Alekseenko et al. (2010) describe the existence of seasonal variations in terrestrial neutron flux caused by tidal effects on the Earth's crust. Salikhov et al. (2013) describe the increase in the flux of neutrons and gamma rays in the environment before earthquakes occur. Ionizing radiation from outer space can also interfere with meteorological and atmospheric processes. Gurevich et al. (1992) suggested that lightning and other types of atmospheric electrical discharges may be initiated by the energetic collision of cosmic rays with atoms in the atmosphere. In pioneering work, Svensmark and Friis-Christensen (1997) suggest that there is a strong correlation between modulation of cosmic ray incidence by varying the solar magnetic field and cloud cover on the planet. Recently, Svensmark et al. (2013) conducted a study in which it was shown under laboratory conditions that particles produced by gamma-ray ionization in the atmosphere form condensation nuclei, suggesting that cosmic rays can influence cloud formation. In national territory, Alves & Martin, 2011; and Martin et al., 2013 have been conducting studies on the variation of environmental gamma radiation and its correlation with atmospheric parameters.

Based on these studies, we sought to determine whether there is a correlation between natural gamma radiation near ground level and cloud cover for a locality.

2 METHODOLOGY

Gamma and X radiation counts in the energy range of 30 keV to 10 Mev are collected by a NaI(Tl) scintillator coupled to a photomultiplier, and the crystal and photomultiplier are housed in an aluminum housing for mechanical protection (Model 44-20 Ludlum, USA). The photomultiplier is powered by a high voltage source of 1400 V, generated from an input voltage of 12 VDC. The pulse signals generated by the radiation in the crystal are amplified and digitized by a compact system (AWARE Electronics USA). A specific software detects the digitized signals and records them on PC computer Cloud cover is measured with an infrared radiometer operating between 9 – 14 µm (model CIR-4V, ATMOS Sarl, France). This instrument measures the fraction of the sky covered by clouds (0% – 100%) between 250 to 8000 m at three levels: 250 to 2000 m, 2000 to 6000 m, and 6000 to 8000 m. Both instruments are installed in São José dos Campos, SP (23° 12' 45" S, 45° 52' 20" W, alt. 620 m). The infrared radiometer is located at the top of the Atmospheric Phenomena Observation Tower of the Institute of Aeronautics and Space, Division of Atmospheric Sciences (IAE-ACA), with an approximate height of 25 m. The gamma-ray detector is housed in an air-conditioned container near the base of the Atmospheric Phenomena Observation Tower (Fig.1). Fig. 2 shows the infrared radiometer at the top of the tower, and Fig. 3 shows the gamma-ray detector inside the air-conditioned container.

The gamma-ray detector and infrared radiometer continuously collect data at 1-minute intervals.

Figure 1 – Tower of Observation of Atmospheric Phenomena (IAE-ACA).

Figure 2 – Infrared radiometer.

Figure 3 – Compact gamma-ray detection system. The scintillator is inside the blue metal case.

3 FINDINGS

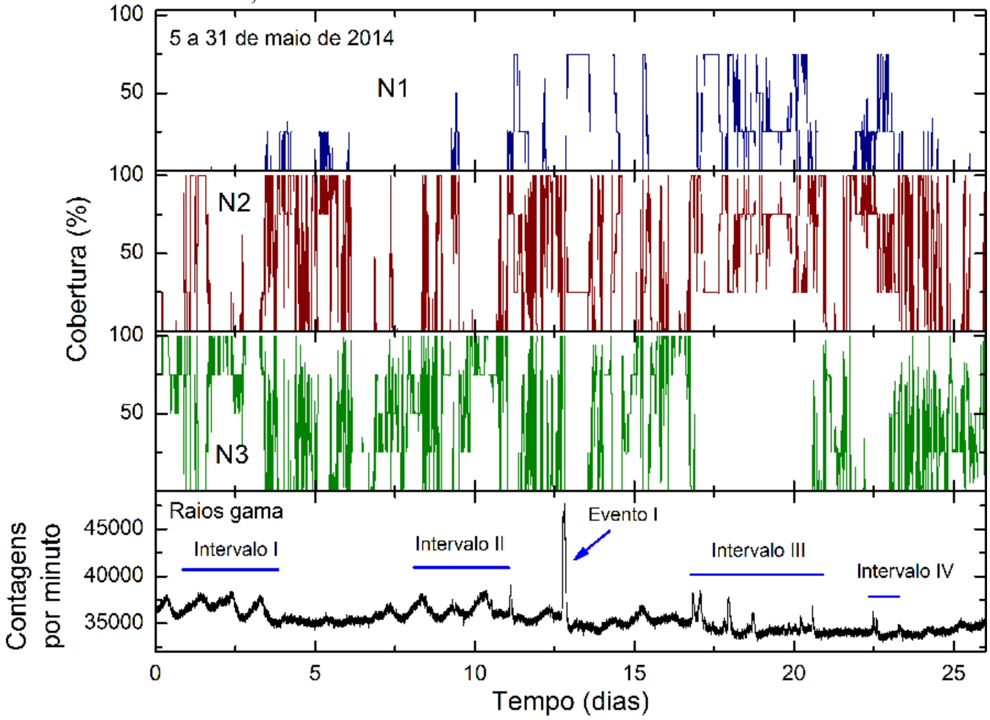
Two time series of cloudiness and gamma ray count were collected between 05/06/2014 and 05/31/2014 (26 days), and 06/01/2014 and 06/24/31 (2 days). The results are shown in Figs. 4a and 4b. In these figures, N1 corresponds to cloud cover at the level of 250 to 2000 m, N2 at the level of 2000 to 6000 m, and N3 at the level of 6000 to 8000 m. The data collection period was relatively dry (few rains), which is typical of late spring and early winter in the region. In the first series (Fig. 4a), we observed an event (Event I, day 13, 19/05/2014) and that corresponds is associated with the occurrence of rainfall. During rains, it is common to occur the process *of radon washout* that consists of the absorption by raindrops of the gas radon-222 present in the atmospheric column and its transport to the soil, thus causing an increase in the local radiation count. The cloud cover after that day is reduced, which corresponds to the passage of the atmospheric front associated with the rains observed in the period.

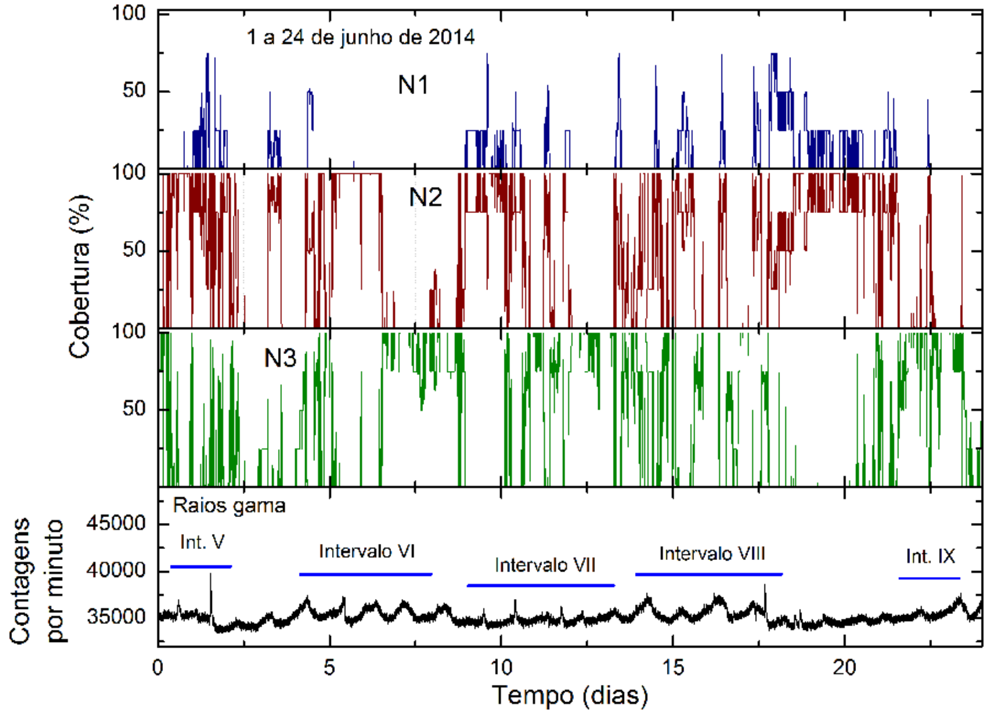
With respect to other variations in gamma ray counting, we observed that in general there is a greater correlation between cloud cover at the N1 and N2 levels and gamma ray counts. For example, during intervals I to IX (Fig. 4a and 4b) we observed a certain degree of correlation between increases in radiation counts and variations in cloud cover. A more careful inspection of these figures. seems to indicate that peaks in gamma radiation counts are associated with higher cloud cover, especially for intervals I, II, III, VII and VIII.

4 DISCUSSION AND CONCLUSIONS

The results presented in this study are preliminary and refer to a period in which rainfall is less common. This study continues and will be extended to include periods with more frequent and intense rainfall (summer, in the region).

Figures 4a (top) and 4b (bottom). Variation in cloud cover at three height levels (N1, 250 to 2000 m; N2, 2000 to 6000 m; N3 6000 to 8000 m) and gamma radiation count. The data shown in Figure 4a were collected between May 6 and 31, 2014; and Figure 4b, between June 1 and 24, 2014.





However, the results obtained indicate that there seems to be a correlation between cloud cover at levels below 6000 m and variation in gamma radiation count at ground level. One hypothesis to explain the results obtained is related to the fact that the Earth's crust continuously releases radon-222 gas into the atmosphere. This gas accumulates in the atmosphere near the ground when atmospheric turbulence is reduced. With the approach of cold fronts, which produce an increase in cloud cover, turbulence near the ground increases, and by mixing process, radon gas is distributed more evenly in the atmosphere. Another hypothesis to explain the observed increase in gamma radiation counts involves the interaction of cosmic radiation with denser clouds (observed at lower levels); Electrons generated by cosmic rays can be accelerated by intense electric fields inside *cumulonimbus* (rain-producing clouds) clouds, giving rise to *Bremsstrahlung radiation* (Vashenyuk et al. 2011).

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