Correlation between Cloud Cover and Gamma Rays at Ground Level in São José dos Campos, SP, Brazil.

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Abstract

Simultaneous measurements with a sampling interval of one minute of cloud cover with an infrared radiometer at three height levels (250 to 2000 m, 2000 to 6000 m, and 6000 to 8000 m) and gamma-ray counts at ground level were conducted in May and June 2014. The results show that there is an apparent correlation between cloud cover and radiation counts. This correlation may be caused by the variation in the local amount radon-222 due to weather phenomena, or the production of gamma radiation due to the acceleration of electrons originating from cosmic rays by electric fields inside rain clouds.

Introduction

The environment is exposed to ionizing radiation produced by various natural and artificial sources. The main sources of natural radiation are cosmic rays and the decay of radioactive isotopes present in the earth's crust (e.g. uranium-238, thorium-232 and potassium-40) and air (radon-222). Often referred to as natural background radiation, the radiation from these natural sources varies around the world according to factors such as altitude, latitude, local geology, meteorological phenomena and geophysical events. The influence of cosmic rays in the environmental background radiation is 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 his discovery of cosmic rays. McCarthy and Parks (1984, 1985) reported the production of X-rays associated with tropical storms using detectors in 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 of associated with the occurrence of lightning. Gurevich et al. (1992) suggested that energetic photons are produced in the collision of relativistic electrons with atoms in the air and that the energy is released in the form of radiation (bremsstrahlung). In addition to X and gamma rays, there is strong evidence that neutrons are also produced by electric discharges. Shah et al. (1985) first described the observation of neutrons produced by atmospheric electric discharges. This production of neutron by lightning discharges has also been observed in observatories located at sea level, low altitudes and on mountaintops (Kuzhevsky, 2004; Martin and Alves, 2010), and on mountaintops (Chubenko et al. 2008). Variations in the thermal neutron flux 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) described the increase in the flow of neutrons and gamma rays in the environment prior to the occurrence of earthquakes. Ionizing radiation from outer space may also influence meteorological and atmospheric processes; in a pioneering study, Svensmark and Friis-Christensen (1997) suggest that there is a strong correlation between the modulation of the incidence of cosmic rays by the variation of the solar magnetic field and the cloud cover on the planet. Recently, Svensmark et al. (2013) conducted a study in which it was shown in laboratory conditions that particles produced by ionization gamma rays in the atmosphere promote the formation of cloud condensation nuclei, suggesting that cosmic rays may influence the formation of clouds. In Brazil, Alves and Martin, 2011; and Martin et al., 2013 have been carrying out 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 at ground level and the cloud cover for a given location.

Method

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

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

Figure 2 – Infrared Radiometer CIR-V4.

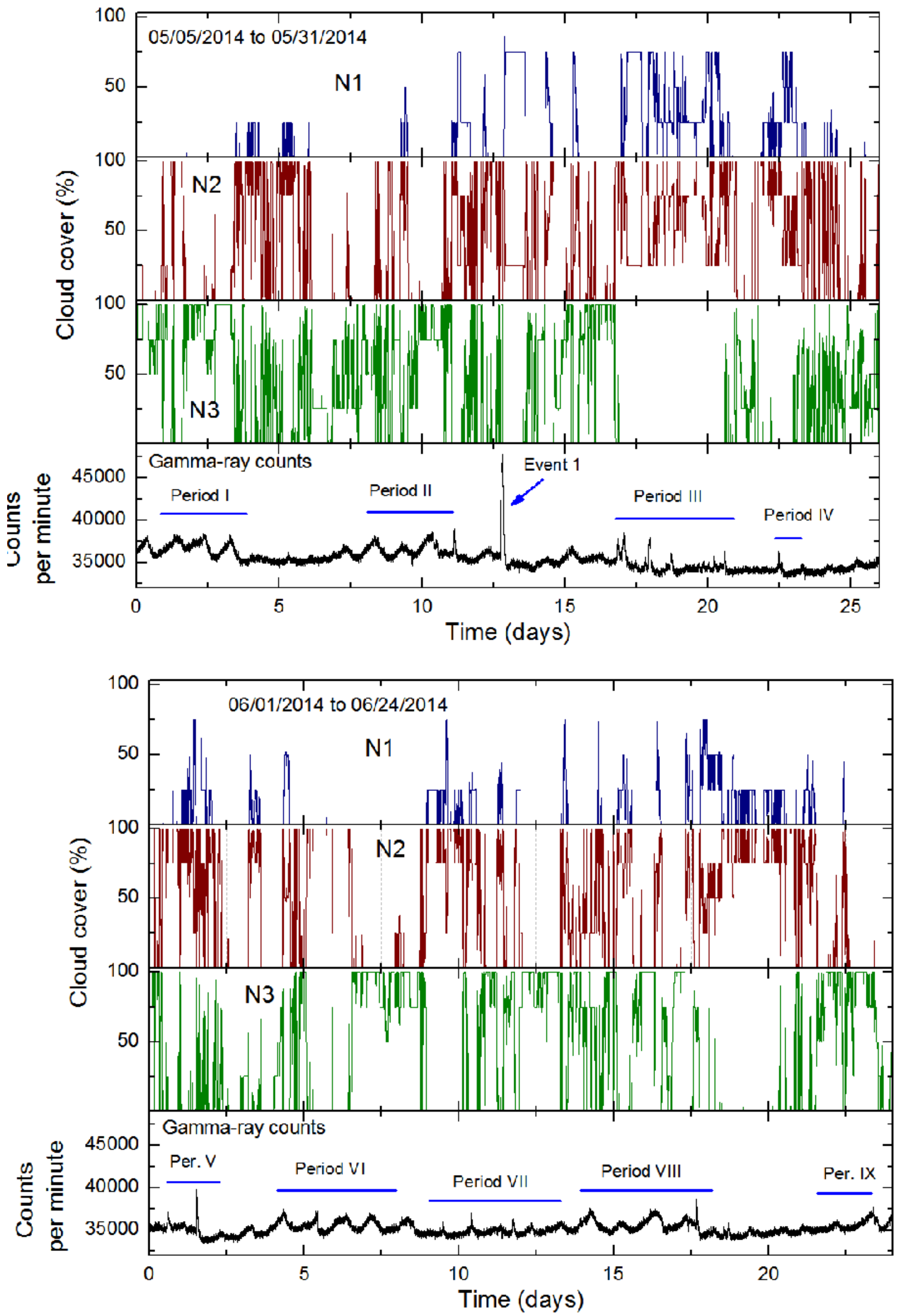
Figure 3 - Compact system for the detection of gamma rays. The scintillator and photomultiplier are inside the blue metal box.

Results

Two time series of cloud cover and gamma-ray counts were collected from 05/05/2014 to 05/31/2014 (26 days), and from 06/01/2014 to 06/24/2014, and (23 days). The series are shown in Figs. 4a and 4b. In these figures, N1 corresponds to the cloud cover at the height level of 250 to 2000 m; N2, 2000 to 6000 m; and N3, 6000 to 8000 m. The data was collected during a relatively dry period, which is typical of late spring and early winter in the region. In the first series (Fig. 4a), we observed an event (Event I, 05/19/2014) that was associated with rainfall. During rain, a common process consisting of the absorption of radon-222 gas present in the atmospheric and its transport to the soil (radon washout), caused an increase in the radiation count. Cloud cover after that day was reduced, corresponding to the passage of a front associated with rainfall observed in the period. With respect to other changes in the gamma-ray count, we found that in general there was a greater correlation between cloud cover in the N1 and N2 levels and gamma counts. For example, during the periods I to IX (Fig. 4a and 4b), we can observe a degree of correlation between increases in radiation counts and changes in cloud cover. A closer inspection of these figures seems to indicate that the peak of gamma radiation counts are associated with increased cloud cover, especially for periods I, II, III and VII.

Discussion and Conclusions

The results presented here are preliminary and correspond to a period in which rainfall is less common. This study continues and will be extended to include periods with more frequent and intense rains (summer in the region). However, these results indicate that there appears to be a correlation between the cloud cover alt levels lower than 6000 m and changes in gamma-ray counts at ground level. One hypothesis to explain the results is related to the fact that the earth's crust continuously releases into the atmosphere radon-222 gas. The gas concentration in the atmosphere is heterogeneous when the atmospheric turbulence is reduced.



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 Fig. 4a were collected from 05/06/2014 to 05/31/2014; and in Figure 4b, from 06/01/2014 to 06/24/2014.

With the approach of cold fronts, which produce an increase in cloud cover, air turbulence near the soil increases and by mixing processes the radon gas is distributed more homogeneously in the atmosphere. Rainfall may result in radon washout, which is responsible for relatively sudden increases in the gamma-ray count. Another hypothesis to explain the observed increase in radiation counts range involves the interaction of cosmic radiation with denser clouds (seen in lower levels); electrons generated by cosmic rays may be accelerated by strong electric fields inside the cumulonimbus clouds (rain producing clouds) and produce bremsstrahlung radiation (Vashenyuk et al. 2011).

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