Measurements of X- and gamma radiation at ground level and their correlation with atmospheric electric discharges and rainfall in São José dos Campos, SP, Brazil.

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Abstract

The main objective of this study was to determine qualitatively whether there is a correlation between measurements of X- and gamma radiation and the occurrence of atmospheric electric discharges and rainfall in the region of São José dos Campos, SP, Brazil. The intensity of the background noise of the X- and gamma radiation in the energy range of 30 keV to 10 MeV was previously determined at ground level under dryer conditions. After determining the background radiation levels, it was possible to measure the increase in count rates of X- and gamma radiation during the occurrence of intense lightning and rainfall over the region of study (ACA tower/IAE).

Introduction

The intense electric field inside a storm cloud (of the order of 10^5 V/m) can accelerate free electrons in the atmosphere to relativistic velocities. The electron avalanche resulting from this process may also start from intense electric field generated by lightning discharges. However, the type of radiation created by this mechanism is still unknown. Experiments with detectors placed in aircraft and also in stratospheric balloons registered an increase of gamma radiation during the production of lightning (EACK, 1996). Detectors located in high mountains recorded events in which gamma rays with energies above 1 MeV were also produced during lightning (MOORE, 2001). Rocket-borne detectors also recorded increases in the intensity of X- and gamma radiation during lightning (DWYER, 2003, 2004). Based on observations made by satellites, Fishman (FISHMAN, 1994) reported that gamma-ray emissions coincided with the location of storms. In 2007, a group of researchers measured gamma ray events with energies up to 1.0 MeV during storms and lightning events (ENOTO, 2008). In Brazil, near Cachoeira Paulista, SP, increases in gamma ray count rate during storms and intense rainfall were also observed(Jayanthi and Martin, 2002).

Method

In this study we analyzed data collected between November 2012 to April of 2013 (one-minute intervals) at the Atmospheric Phenomena Observation Tower, (Figure 1), of the Institute of Aeronautics and Space (IAE-ACA), in São José dos Campos, SP, Brazil. Measurements of X- and gamma radiation in the range of energies from 30 keV to 10 MeV (counts/minute) and atmospheric electric field were recorded simultaneously and compared with lightning strike records. Measurements of X- and gamma radiation, were carried out using a scintillator crystal of sodium iodide activated with thallium [NaI(Tl)] coupled to a photomultiplier, with energy resolution of 15% (Figure 2). Records of lightning strikes were provided by the Brazilian Lightning Detection Network (BrasilDat) operated by National Institute for Space Research (INPE). Rainfall, atmospheric pressure and temperature, and relative humidity were recorded (one-minute intervals) with sensors (Figure 2) coupled to a five-channel specific data logger (Martin, 2013).

Figure 1: View of (A) ACA Tower in São José dos Campos, SP, Brazil, (B) instrument trailer, and (C) meteorological station.

Figure 2: Trailer and instruments inside the trailer at the ACA Tower. Note the pluviometer at the top of the pole attached to the side of the container.

Results

During the study period, we observed that there was a strong temporal correlation between the increase in the magnitude of the atmospheric electric field due to the presence of storm clouds and increase in X- and gamma count rates (Figure 3).

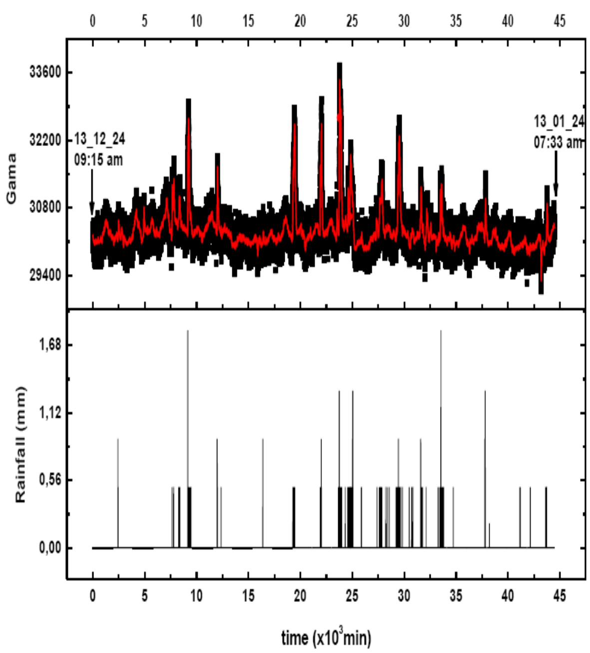

Figure 3: X- and gamma rays measurements and rainfall data from 12/24/2012 to 01/24/2013. Sixty-minute smoothed average of the count rates is shown in red.

Variations in the electric field caused by the presence of electrified clouds over the study region coincided with an increase in radiation counts. Although it was not possible to quantify the contribution of lightning discharges, increases in gamma radiation counts were recorded during the occurrence of storms (Figure 4).

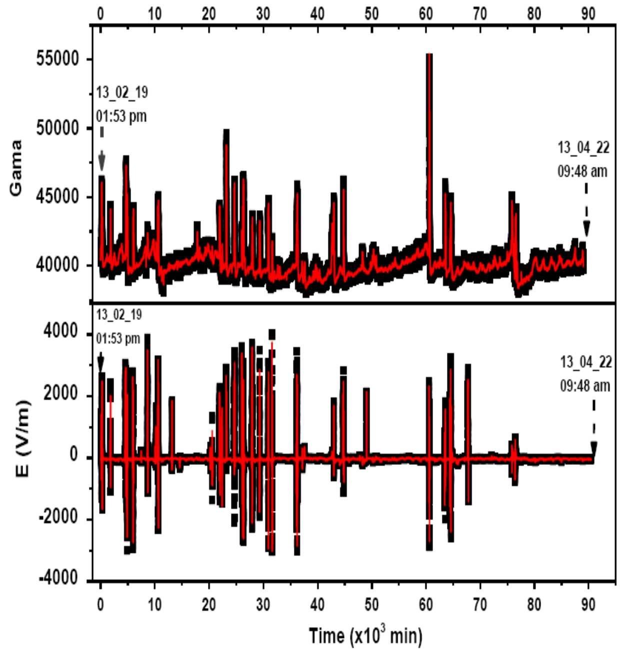

Figure 4: Atmospheric electric field data and X- and gamma count rates measured from 02/19/2013 to 04/01/2013 at the ACA Tower. Sixty-minute smoothed averages of the raw data are shown in red.

To clarify this problem, it will be necessary to collect additional data on atmospheric electric field variations and the spectra of gamma radiation resulting from the radioactive decay of radon gas before, during and after rainfall since radon is an important source of environmental radiation. Preliminary studies of the profiles of the peaks of gamma radiation as a function of time indicate that there is a difference between the profiles that were recorded during rainfall and the occurrence of lightning compared with periods when there is no rain. During rainfall without lightning, the profiles of the lines tend to have a symmetric Gaussian shape. During lightning storms the profiles of the peaks are describe by an asymmetric double sigmoid function. But, it was also observed that some of the peaks have shapes that can be fit by a Voigt function (Figure 5).

Figure 6 shows the X- and gamma count rates during a rainy period (03/10/2013 to 04/25/2013). The background count rate remained around 40000 counts/minute, but during rainfall it peaks to values above 44000 counts/minute. Measurements around 60000 minutes coincided with the occurrence of a very intense rainfall that resulted in the production of X- and gamma rays with count rates 40 % above the background level of the region.

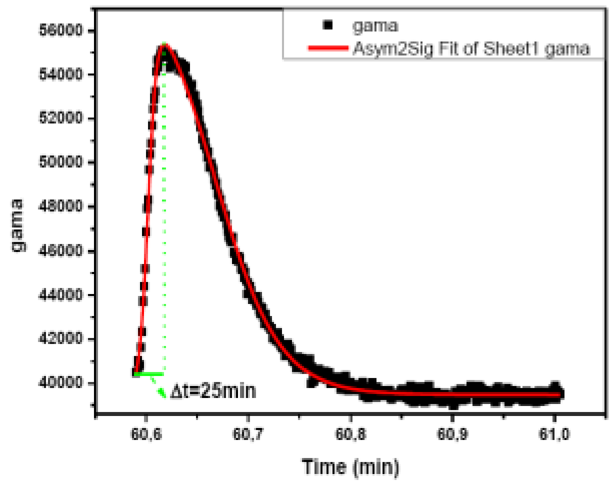

Figure 5: Profile of a radiation peak (black) fit with a sigmoid function (red).

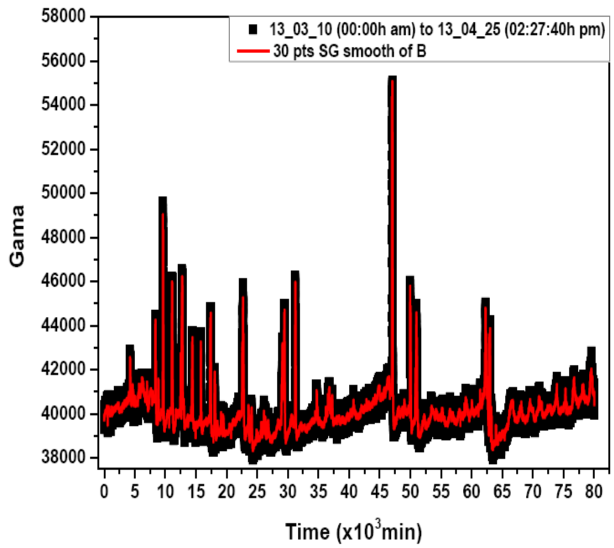

Figure 6: X- and gamma ray count rates during a rainy period (03/10 to 04/25). Sixty-minute smoothed average of the count rates is shown in red.

Conclusions

During the study period, we observed that variations in the atmospheric electric field caused by the presence of electrified clouds over the study region were correlated with increases in the X- and gamma ray count rates. This result is in agreement with those previously reported in the literature. The correlation between variations in the X- and gamma ray counts and changes in the atmospheric electric field as well as changes in the profiles of gamma ray count peaks in the presence and absence of lightning activity associated with storms suggests that lightning probably play an important role in the production of X- and gamma radiation during of storms. We also observed an important contribution due to the radioactive decay of radon gas to the X- and gamma radiation count rates in the study region.

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