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AMBIENT NEUTRON AND GAMMA MONITORING IN BRAZILIAN TROPIC

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ABSTRACT

São Jose dos Campos (SP, Brazil, 23°11′S, 45° 52′W, 650 m high) is one of the most important industrial and research centers in Latin America with emphasis in aerospace science and technology. It is a site of the Brazilian National Institute for Space Research (INPE), Brazilian General Command for Aerospace Technology (DCTA), Embraer (one of the largest aircraft manufacturers in the world), and Avibras (company designing, developing and manufacturing defense products and services). Due to that, atmospheric studies are one of the priorities developed there. The INPE and the Technological Institute of Aeronautics (ITA), which is part of the DCTA, implement a wide program of meteorological, stratospheric and environmental research. Monitoring of natural and environmental radioactivity is one part of it. Facilities for this include several gamma NaI(Tl) detectors of various volumes and a neutron gas-discharge detector.

Keywords: *neutrons, gamma rays, rainfalls, radon gas, lightning.*

I. INTRODUCTION

At the ground level interface of the Earth's surface, ionizing radiation it is composed mainly of gamma ray, soil telluric radiation, primary and secondary cosmic ray radiation [1, 2,3]. 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 and ^{232}Th disintegration's series that are constant for each region. The gamma ray coming from radon gas arriving through the ^{238}U in Earth's crust disintegration to ^{226}Ra and ^{222}Rn reaching the stables isotopes ^{214}Pb, ^{214}Po and ^{214}Bi.Radioactive elements such as Uranium, Thorium and Potassium are found in almost all types of rocks, sands, soils and water [4]. The Radium ^{226}Ra and its decay products are responsible for a major fraction of the dose of internal emissions received by humans. ^{226}Ra has a half-life of 1,600 years, and decays to Radon ^{222}Rn, which has a half-life of 3.82 days. The decay of ^{222}Rn is followed by successive disintegration of short half-life alpha, beta and gamma ray emitters. After decay stages, the radioactive chain ends with stable lead ^{206}Pb. With regard to soils and rocks, the ^{226}Ra is present in virtually all soils and rocks in varying amounts. Areas with high levels of background radiation found in some soils are due to geological conditions and geochemical effects and cause increased terrestrial ionizing radiation. Researches in the world, and specifically in Brazil, show these conditions. Several studies report variations throughout the day of radon concentrations. Maximum concentrations are observed in the first hours of the day and the lowest values are found late near afternoon, when concentrations are about one third of morning values. The same profile is observed with the gamma ray intensity variation in the tropics region. However, it is likely that variations in concentrations in localities of gamma ray intensity are dependent on local meteorological parameters (rain, wind, pressure, temperature and cloudiness) in the gamma ray detector site [5, 6].Electrical discharges in low atmosphere of the region also can contribute with production of low energy gamma raynear ground level.

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II. METHOD & MATERIAL

To monitor the gamma radiation in interval between 200 keV to 10.0 MeV, it has been used a portable system. Detector composed of sodium Iodide scintillator activated with Thallium NaI(Tl).This crystal 3" x 3" inches (diameter and height) placed in a thin cylinder of aluminum foil and coupled with a PM (photomultiplier) with source power circuit settled in 1500 VDC and with data acquisition system provided by the company (Aware Electronics-Inc., USA)[7]. Detector and associated electronics of gamma ray were previously calibrated in ITA (Technological Institute of Aeronautics) laboratory using radioactive sources Cs-137 and Co-60 in terms of energy from emitted photons 662 keV and 1,17 MeV, 1,33 MeV respectively [8]. The data acquisition in terms of gamma radiation and intensity of rainfall was performed using 1-minute time interval between each measurement. This detail contributes to verify possible correlations between variation of rain intensity, and local ionizing radiation [9]. In Figure 1 it is shown the measurements region of São José dos Campos city in Brazil. The number of lightning per year and per km^2 in the region o measurements arrive to 40 (mean value).

Fig. 1 - Geographical location of Sao Jose dos Campos.

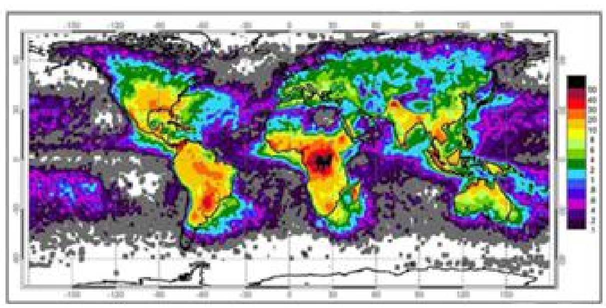

Fig. 2 - Frequency of lightning strikes per km^2 per year. The frequency of lightning strikes at São José dos Campos is about 20-40 strikes /km^2·year.

III. RESULT & DISCUSSION

1 - Radon progenies - Monitoring of radon progenies is of special interest because Brazil is likely a place with the highest level of primordial radioactivity on the globe. Curiously, the natural product with the highest radioactivity is called "Brazil Nut".The observed spectrum of gammas suggests the presence of radon progenies from both of ^{238}U, ^{232}Th series and primordial ^{40}K.A clearly visible in Fig.1 diurnal periodic -flux variation is controlled by small-scale eddy dynamics of the low atmospheric boundary layer due to variations of the temperature and humidity of the atmosphere and soil during the day. Intensive tropical rainfalls characteristic for the locality are accompanied by a fast increase of the radioactivity during precipitation followed by exponential decline with mean time of about 60 min characteristic for progenies of ^{222}Ra. Several sharp peaks of the enhanced intensity in Fig.3 correspond to rainfalls of various intensities. Enhanced amplitudes of three early-morning diurnal maxima (April 12, 13, and 15, 2012) coincide with fogs. Examples of rainfall gammas profiles are shown in Fig. 4 a and b. Their shape are

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determined by a balance between intensity I_{214Pb} of ^{214}Pb fallout from a rain cloud and the consequent decay of accumulated ^{214}Pb:
$^{214}Pb \rightarrow {}^{214}Bi \rightarrow {}^{214}Po \rightarrow {}^{210}Pb$.

The process is described with a system of two differential equations:

$$\frac{dN_{214Pb}(t)}{dt} = I_{214Pb}(t) - N_{214Pb}(t)/\tau_{214Pb}$$

$$\frac{dN_{214Bi}(t)}{dt} = I_{214Pb}(t) - N_{214Pb}(t)/\tau_{214Bi}$$

Due to a short period of ^{214}Po decay (164.5 μsec) its input to the total gamma intensity is equal to that from ^{214}Bi. Total γ-flux:

$$F_{g-tot}(t) = N_{214_{Pb}}(t)/t_{214_{Pb}} + N_{214_{Po}}(t)/t_{214_{Po}} + N_{214_{Bi}}(t)/t_{214_{Bi}}$$

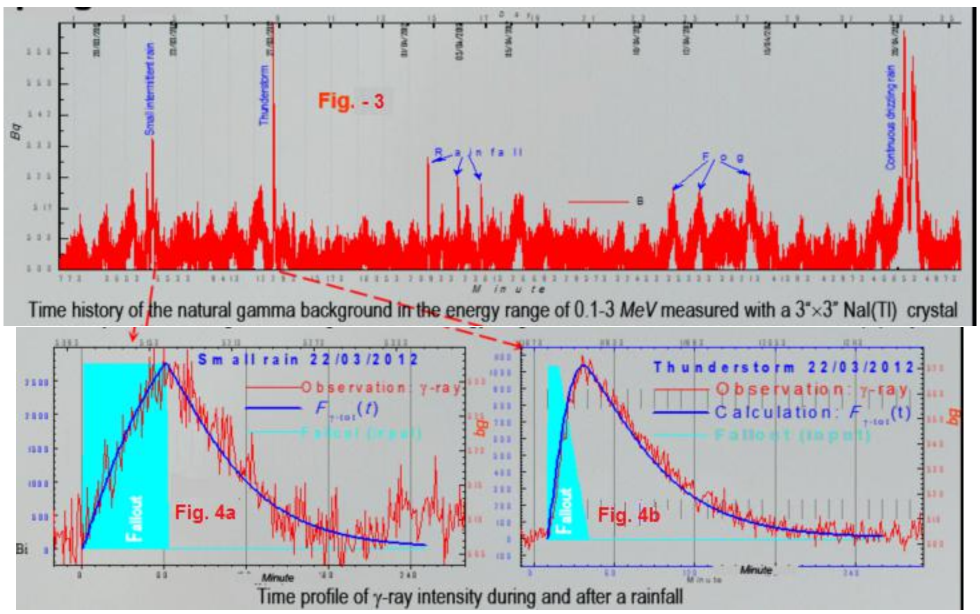
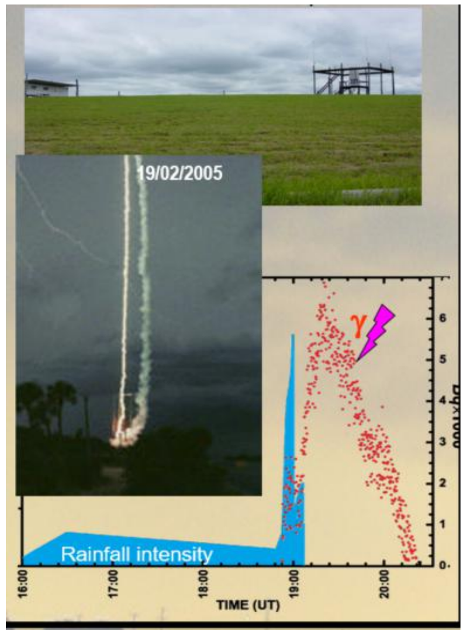


Fig. 3 gamma rays from 03/18/2012 to 04/22/2012 and Fig. 4, a and b, rains curves.

2 - Artificial lightning - The measurements was performed with a large 16"×2" NaI(Tl) crystal with 19 PMT.To protect the detector and the electronic circuit of electromagnetic background the whole device was shielded with a Faraday Cage, lightning protectors and powered with an autonomy battery source with no break system.

Artificial lightning – Fig 5

The device was installed between two rocket lunch powers in INPE campus in Cachoeira Paulista – SP, a rain forest valley region. The graph demonstrates a flicker of gammas at the background of a decrease of after rainfall γ-emission [10].



Artificial lightning – Fig 6

3 - Naturallightning- Gamma emission

Another instrument used for detection of gammas from lightning consists of four independent scintillation detectors with 3”×3”NaI(Tl) crystals. The figure demonstrates impulses produced in the detectors by γ-quanta emitted in a lightning stroke.

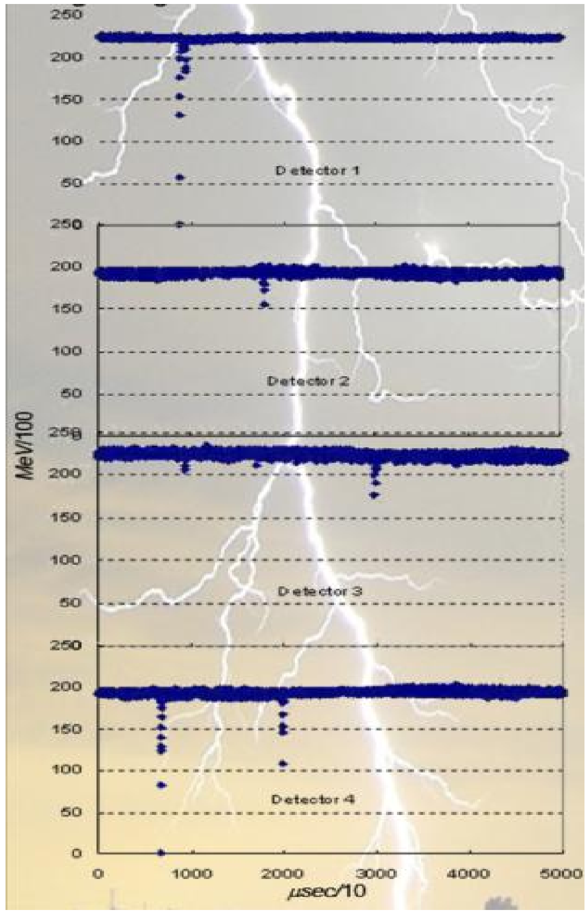


Fig. 7 -Gamma emission from lightning period

4 - **Naturallightning- Neutron emission**
A standard He^3 detector (Lundlum® tube of 250 *cm²* area, pressure 3800 *Torr*, operating voltage, 1450 *V*), was used for the measurements. Neutron registration efficiency of such detector tube is inversely proportional to neutron energy, reaching about 80% for thermal neutrons. The detector was calibrated in a nuclear instrumentation laboratory, using a source of (Am-Be) in ITA laboratory.

During a lightning storm at the moment of a lightning, discharge that occurred in very near the tube detector (< 0.5 *km*), the neutron count rate increased to about 690 neutrons/minute within less than one minute.

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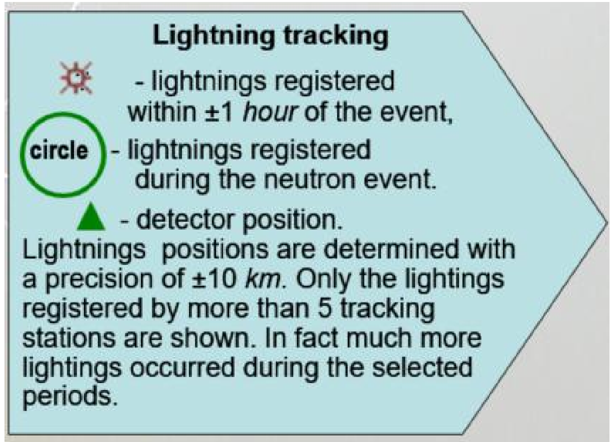

Neutron emission site – Fig 8

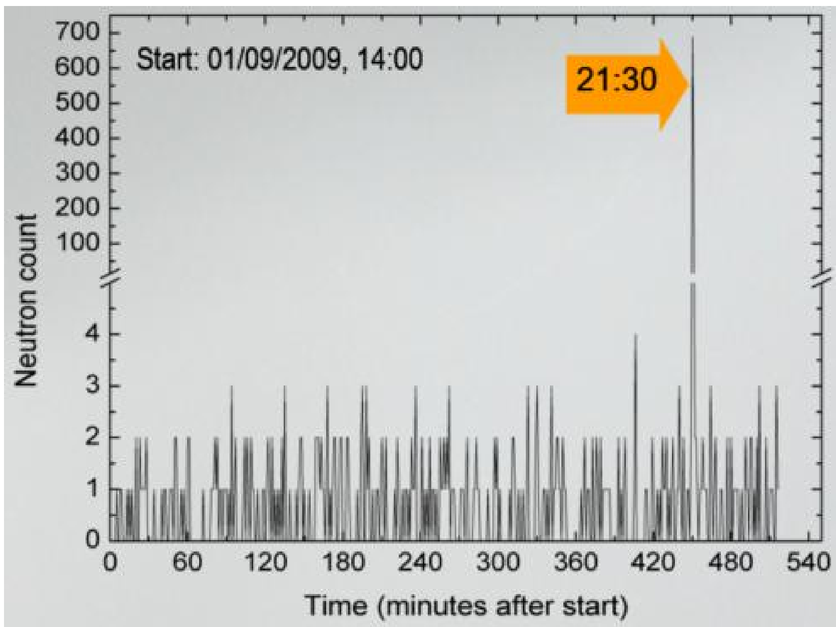

Fig. 9 – Observation of neutron burst due to lightning presence in site.

Figure 10 below shows with a green arrow the neutron detector and the location where it was

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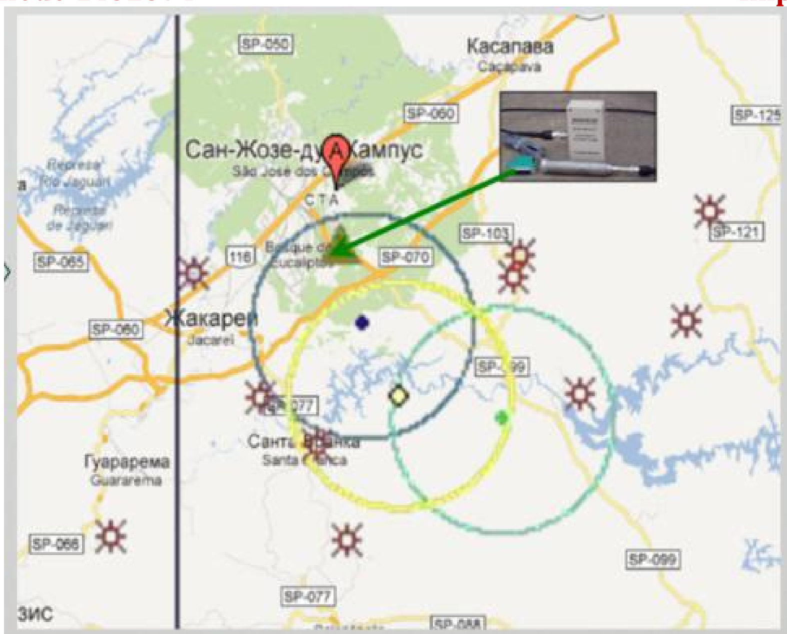

Fig. 10 – Neutron detector and place were the lightning occurred.

During this night a great number of lightning crossing the sky region that was observed in site by the first author. The background of neutrons counts rate from 2-3 increasing to 690 neutrons/minute with the lightning presence in site.

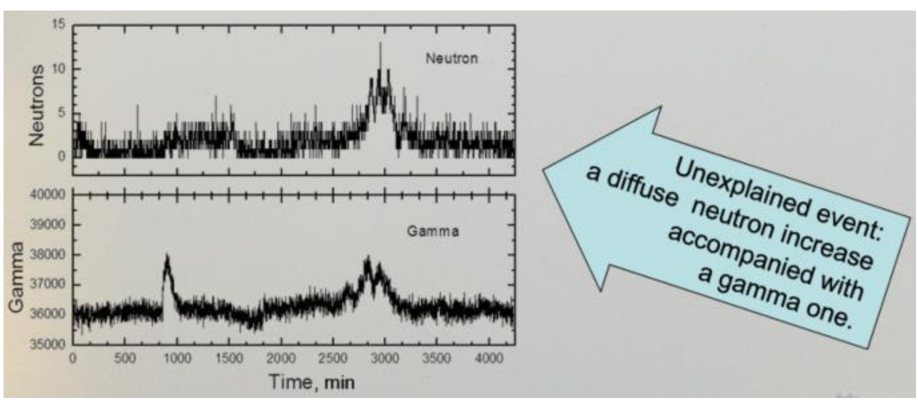

Fig. 11 – Unexplained event of neutron and gamma ray occurred in the place without electrical discharges or rainfalls in the site occurred in 05 April 2013 at 11:00 local time. No seismic event was registered in this day.

IV. CONCLUSION

Research on the dynamics of gamma radiation, rainfall intensity and thermal and epithermal neutron counts were made based on measurements of these parameters in the region between 2009 and 2013. With instruments to measure these parameters installed in a tower of 25 meters in height with precision in time of one minute for all measures, it was possible to verify correlations between them. It was possible to show correlation between intensities of rains with intensity of gamma radiation. The same happens with intense rains and intensity of thermal and epithermal neutrons. For the first time in South America, a neutron burst was detected during a lightning event at the same location [11]. It was triggered an artificial lightning and shown the gamma radiation caused by it. A correlation between gamma rays and thermal and epidermal neutrons were also measured in a natural phenomenon in the unknown and / or registered environment.

V. ACKNOWLEDGEMENTS

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