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Measurement of Ambient Neutrons in Correlation with Weather during July-August, 2017, in São José dos Campos, SP, Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. Author IMM designed the study, performed data control and the statistical analysis, and wrote the first draft of the manuscript. Author FAS graduated student elaborated all graphics and author MPG managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This work shows near-ground measurements of neutrons in the energy range of (0,03 eV to 10.0 MeV) performed at 1-minute intervals from July to August 2017. This monitoring was done in this period where there was dry weather in July and half of August. Between August 15th and the beginning of September, there were rains totaling 27 mm of intensity in the measurement region. Environmental neutrons measured at this energy range show a reasonable increase in their intensity in the rainy period. This observation is in agreement with the international project "COSMOS" whose objective is to show the increase of the intensity of neutron near the surface of the Earth with wet soil. With the use of a simple portable detector system for monitoring measurements, it was also possible to see the **(day/night)** variation in the region, formed by the presence of Rn-222 radon gas. The local presence of this gas emits particles **α** and **β** that hit the soil and air producing neutrons.

Keywords: Neutron measurements; weather; radon gas.

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1. INTRODUCTION

Thermal, epithermal and fast neutrons in the energy range (0, 03 eV to 10.0 MeV) are always present approximately the Earth's surface with their intensity varying in time [1]. However, the presence of rain in the region of environmental monitoring is the main parameter that causes the increase of its intensity [2]. Also the presence of intense electrical discharges between clouds and the surface of the Earth can provoke neutron bursts in short intervals of time at the monitoring site [3].

The Earth's lower atmosphere undergoes interactions of particles and photons coming from space and also from Earth's soil. Those that originate in the soil are always the same for a specific region such as São José dos Campos, SP, Brazil, which originate from the earth's crust mainly from radon gas exhaled from Earth. This is due to the disintegration of primordial Uranium ^{238}**U** into Radium ^{226}**Ra** and Radon ^{222}**Rn**. These radiations are alpha particles of 5.450 MeV, beta particles of 3.275 MeV and gamma rays of 0.609 MeV preferably. Due to the horizontal and vertical winds, this radon gas is enclosed in the air near the surface until altitudes of 500 meters above the ground [4]. Through a gamma ray detector, charged or alpha particle detector it is possible to measure the variations in time of the local radon gas. This research work is being done since 2013 in ITA-Technological Aeronautics Institute, São José dos Campos, SP, Brazil by the group ATMOSRAD (Atmospheric Radiation) (see main articles already published) in:

> https://drive.google.com/drive/folders/0B8c-zUww_B1zWWp2T1QySUVIODA?usp=sharing

The environment is exposed to ionizing radiation emitted from different types of sources existing in nature. Radiation from these natural sources varies around the world according to factors such as altitude, local geology, meteorological phenomena and geophysical events [5]. Recorded the production of X-rays associated with tropical storms with detectors installed in stratospheric balloons and aircrafts. [6] described for the first time the production of gamma rays by electrical discharge in high atmosphere using data collected by an observatory in terrestrial orbit. Author [7] used NaI(Tl) scintillators located on top of a mountain to detect gamma-ray flashes associated with the occurrence of lightning. Researchers from [8] 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 electric discharges. The author [9] described for the first time the observation of the production of neutrons by atmospheric electrical discharges. This type of phenomenon has been, for example, seen in observatories located at sea level [10] and on top of mountains [11]. Researches on (2007) [12] suggest that neutrons are produced in photonuclear reactions as part of processes that occur during the avalanche of relativistic electrons in the atmosphere.

Variations in the thermal neutron flux may also be related to seismic phenomena [13] and [14] describe the existence of seasonal variations in the terrestrial neutron flux caused by tidal effects in the Earth's crust. In 2013 [15] describe the increase in neutron flux and gamma rays in the environment prior to the occurrence of earthquakes. In these cases, gamma radiation and neutron levels are probably related to the interaction of alpha particles with atoms in the atmosphere. Alpha particles are an intermediate product of the radioactive decay of radon gas (Rn-222) which is released more from the Earth's crust during seismic events and hotter time in dryer soil.

Ionizing radiation from outer space can also interfere with meteorological and atmospheric processes. Researches in (1992) [8] have suggested that lightning and other types of atmospheric electrical discharges can be initiated by the energetic collision of cosmic rays with atoms in the atmosphere. These collisions produce avalanches of electrons that serve to "start" the lightning [16], in pioneering and controversial work, suggested 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 coverage of clouds on the planet, with influence on global climate. Also, in 2003 [17] carried out a study in which it was shown experimentally (under laboratory conditions) that particles produced through the ionization by gamma rays in the atmosphere form condensation nuclei, which shows that the cosmic radiation that affects the planet could influence the formation of clouds. This research is still now being verified.

2. MATERIALS AND METHODS

For the neutron measurements reported in this work a neutron detector made of a tube of (He-3) gas based on Ludlum (LND, USA; model 25311) with a sensitive area of approximately 250 cm² was used [18]. The detector was employed to detect and record thermal, epithermal and fast neutrons at ground level in the energy range of 0.03 eV to 10.0 MeV, during July and August of 2017 in São José dos Campos, SP, Brazil (23° 12' 45" S; 45° 52' 00" W). The detector and other hardware were placed in a room inside a tower above ground level in the Institute of Aeronautics and Space – IAE - (Fig. 1).

Fig. 1. Overview of the outside of the room inside the IAE tower where the neutron detection system with associated electronics is placed

Source: Project Atmosrad 2017

The analog signals are converted into digital signals by an embedded circuit (PMI-30) which also feeds the (He-3) tube that permits varying the voltage from 600 to 1800 VDC, technical details are available on the US company's website (Aware Electronics Inc. - USA) [19]. Tests and trials were carried out with this tube and associated electronic system with data acquisition using a neutron source of (Am-Be)-241 in the laboratory. The counting signals were accumulated for 1 minute and then were saved in a .txt file. To study neutron background radiation in this energy range in the equatorial and tropical regions with a tube with a sensitive area of ~ 250 cm2, the sampling time of 1 minute provides the best performance. Throughout the period of measurement, the temperature inside the room was maintained at (20 ± 1)ºC. From July to August 2017, this experimental set was always monitoring the intensity of neutrons present in the Applied Meteorology Center (ACA) of the Institute of Aeronautics and Space (IAE), in São José dos Campos, SP, Brazil [20]. The method used to visualize the measures proposes collecting the data every two days without deleting the general file which was saved to a Dell 630 laptop. Through Excel and Origin 8.5 software a graph was made of the period measured, showing intensity of neutrons per minute versus time. So with this chart we could verify normal background noise radiation or if there had been during this time a different variation which indicates the presence of another generating source such as lightning, rain and thick clouds crossing the region. Also the research in the oceans [21,22,23], can explain the speed with which the global environment of planet Earth changes.

3. RESULTS AND DISCUSSION

Throughout the monitoring period of the neutrons, the temperature outside of the room inside the tower was 10° to 25°C and relative humidity varied from 30% to 60% during the measurements. During the monitoring period, no lightning or electrical discharges of any value were recorded. Therefore, there were no ionizing radiations produced by this type of atmospheric phenomenon at the studied site. In Fig. 2 the radiation monitoring is shown every minute of the months of July and August of 2017, with the detector placed in the room above the tower seen in Fig. 1.

The green line in this Fig. 2 gives smoothed curves for each day of neutron intensity measured.

It can be seen in Fig. 2 that between 45 and 65 x 10^3 minutes there are small changes in the intensity and variation of the measured neutrons. This was caused by a moderate rain that fell in the region starting July 7, 2017, as shown in Fig. 3.

Other times, there was no rain, drizzle or even fog. In Fig. 3 (b) the rainfall monitoring between June 30th and September 4th of 2017 is shown. The net amount of rain in this period was 27 mm, indicating that there had been only the rains previously shown in Fig. 3(a).

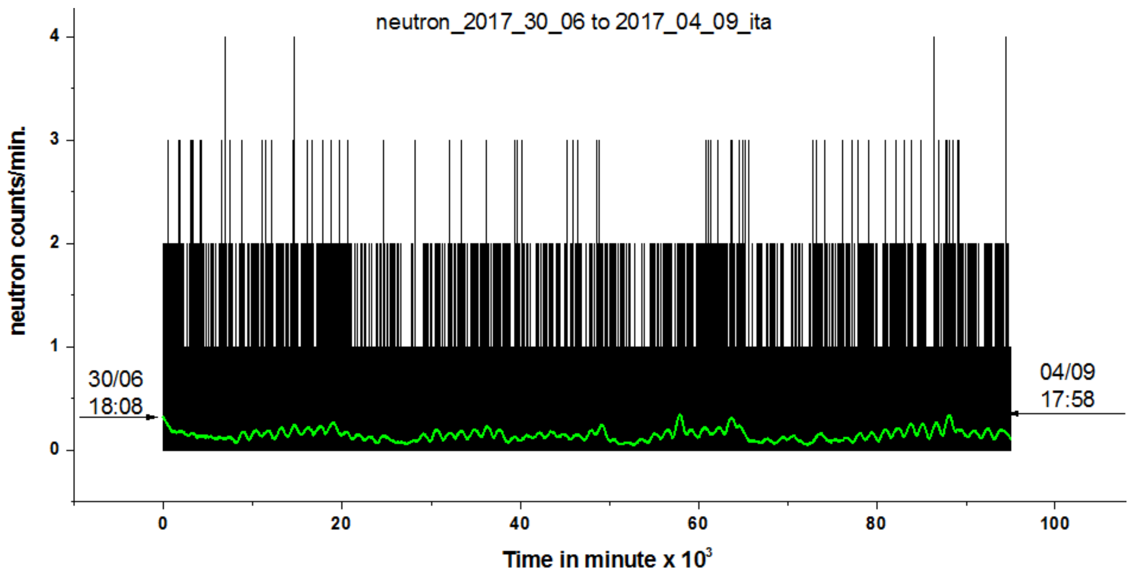

Fig. 2. Neutron monitoring from June 30th to September 4th of 2017
Source: Project Atmosrad 2017

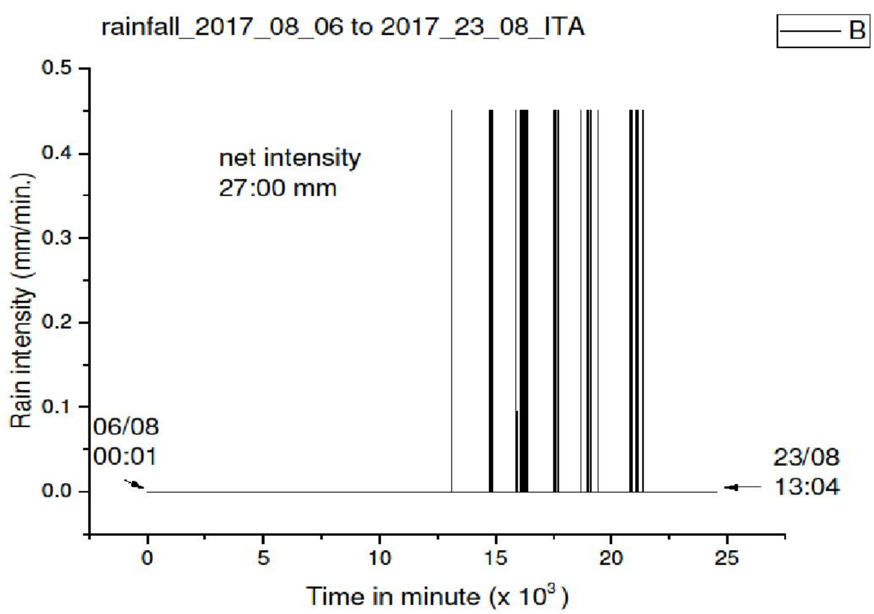

Fig. 3(a). Monitoring of rain intensity from August 1st to September 4th of 2017 between 13 and 23 x 10^3 minutes corresponding to one week with low and moderate rainfall in the region
Source: Project Atmosrad 2017

Fig. 4 shows the measurements of neutrons in the period of one week, in which the atmosphere was under the influence of rain, corresponding to the time between 13 to 23 x 10^3 minutes, as seen in Fig. 3(a). It is possible to see that in this period there was a minor increase in the intensity of measured neutrons. Because the Earth's surface in the region is very dry and the amount of rain was moderate, this increase was barely noticeable.

Fig. 5 shows the monitoring period without any rain or clouds in the sky, indicating the intensity of neutrons periodically in time. They are produced on the Earth's surface by influence of the presence of radon gas (Rn-222), which carries **α** particle that interacting with the metallic chemical elements of the soil produce low energy neutrons. In this case, the periodicity is of one day due to the effect of insolation in the tropical region, where the average temperature is maximum in the position of the solar zenith that corresponds to ~ 12:00 local time. As long as the region under measurement is cloudless the direct insolation determines the variability of the neutron intensity in the energy range of E< 10.0 MeV. This behavior of the neutrons present in the region can be seen in Fig. 5.

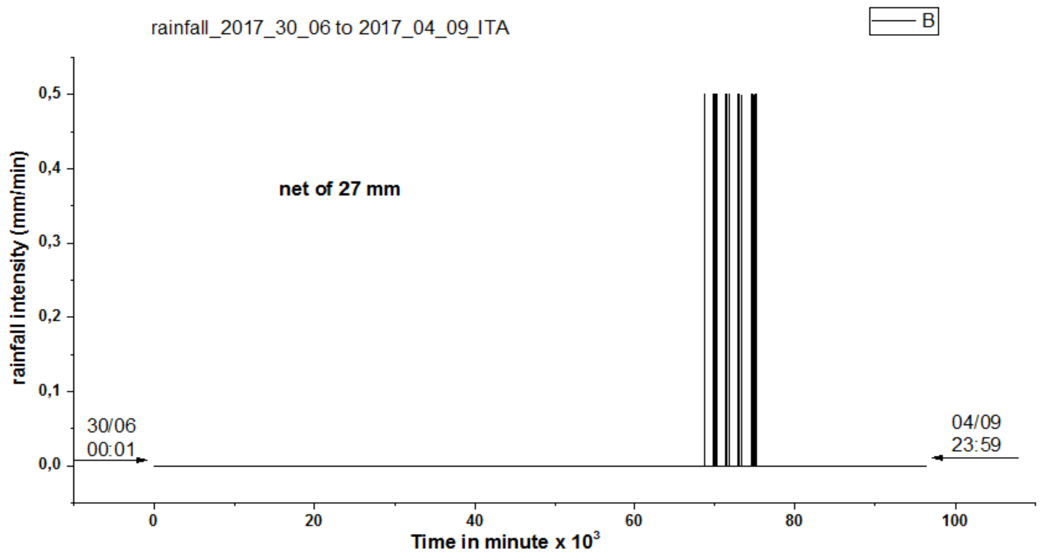

Fig. 3(b). Monitoring of rain intensity between June 30th to September 4th of 2017 showing the same amount of rain as in Fig. 3 (a)
Source: Project Atmosrad 2017

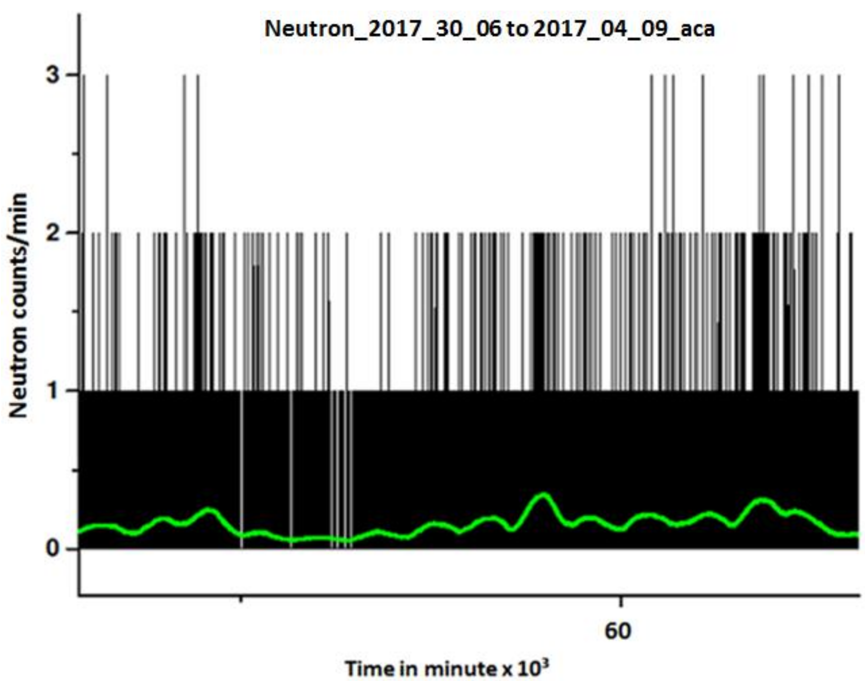

Fig. 4. The period of measurement of ionizing radiation between 45 and 65 x 10^3 minutes related to Fig. 2 with moderated increase in neutron intensity
Source: Project Atmosrad 2017

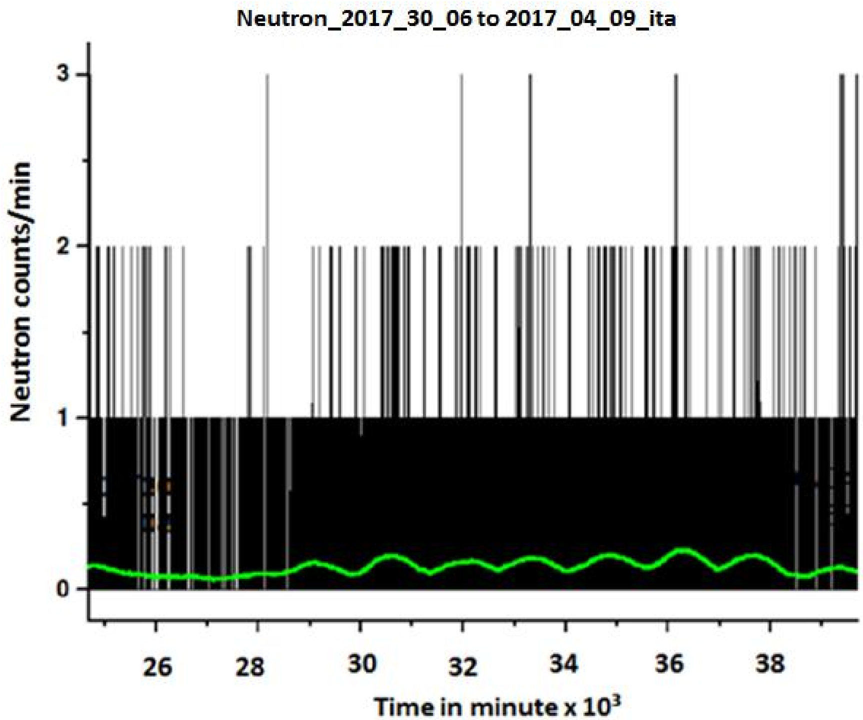

Fig. 5. Monitoring of the neutrons during the period without rains clearly indicating the day / night periodicity

Source: Project Atmosrad 2017

Note that this period shown in Fig. 5 is disturbed by cloudy skies with intense clouds and fog in the region, but no rainfall. This happened between 25 to 29 x 10^3 and after 38 x 10^3 minutes.

4. CONCLUSION

In the period of July to September of 2017, the intensity of rains was monitored every minute and in the same place and same time, the intensity of neutrons was measured every minute. The analysis shows that during the single week of moderate and weak rains there was a moderated increase in the intensity of neutrons. The total rainfall in the period was 27 mm distributed in time, as shown in Fig. 3 that report the difference caused by the rains in the measurements of neutrons. Also in this work, the perfect oscillation of the neutrons (day / night) in the dry period is evidenced, without cloud, fog, or others. The exhalation of the radon gas (Rn-222) in this region causes this oscillation with higher intensity during the local solar zenith. The alpha particles of this gas interact with the metallic materials of the local terrestrial surface generating the neutrons that were monitored in the period in question.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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