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Preliminary results on soil-emitted gamma radiation and its relation with the local atmospheric electric field at Amieira (Portugal)

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Abstract. The atmospheric electric field near the Earth's surface is dominated by atmospheric pollutants and natural radioactivity, with the latter directly linked to radon (^{222}Rn) gas. For a better comprehension on the temporal variability of both the atmospheric electric field and the radon concentration and its relation with local atmospheric variables, simultaneous measurements of soil-emitted gamma radiation and potential gradient (defined from the vertical component of the atmospheric electric field) were taken every minute, along with local meteorological parameters (e.g., temperature, atmospheric pressure, relative humidity and daily solar radiation). The study region is Amieira, part of the Alqueva lake in Alentejo Portugal, where an interdisciplinary meteorological campaign, ALEX2014, took place from June to August 2014. Soil gamma radiation is more sensitive to small concentrations of radon as compared with alpha particles measurements, for that reason it is more suited for sites with low radon levels, as expected in this case. Preliminary results are presented here: statistical and spectral analysis show that i) the potential gradient has a stronger daily cycle as compared with the gamma radiation, ii) most of the energy of the gamma signal is concentrated in the low frequencies (close to 0), contrary to the potential gradient that has most of the energy in frequency 1 (daily cycle) and iii) a short-term relation between gamma radiation and the potential gradient has not been found. Future work and plans are also discussed.

Keywords: atmospheric electric field, ^{222}Rn , air ionization

1. Introduction

Atmospheric electrical conductivity is mainly caused by air ions [1], as they are responsible for most of the electric charge transport in the surface atmospheric electric field. Typically, the Potential Gradient (PG) is used as a measuring means to observe such variations in the atmospheric electric field, which is defined to be positive in fair-weather (FW). The two major contributors for air ions in the lower troposphere are cosmic rays (~20 %) and natural radioactivity [2], with the latter being



directly linked to radon (^{222}Rn) exhalation and mixing processes above soil surface. With an half-life of 3.82 days, radon can move from the solid grains into the air or water-filled pores of the media and further migrate via diffusion and/or advection to the atmosphere. Once in the atmosphere, the radon decay products induce air ionization through the emission of alpha particles, allowing the increase of air ions concentration and of the atmospheric electric conductivity; this causes a decrease in the local PG [3-4], while aerosols and water-droplets are the two main causes for air ions suppression and, consequently, tend to increase the PG.

In order to have a better comprehension of the temporal variability of PG and soil-emitted gamma radiation time series, the present work addresses a preliminary study on measurements of both parameters at a local scale.

2. Data and methodology

The region of study is Amieira, which is part of the largest artificial lake in West Europe as the result of the Alqueva dam, in the countryside of Portugal (Alentejo). A set of particular local features includes low pollution levels and a stable geological activity (an inactive seismic fault exists beneath the dam). All the presented data were acquired in an inter-disciplinary meteorological campaign ALEX2014, during an observational period of 3 months (June to August 2014). The campaign main focus was the study of the possible impact of the Alqueva reservoir in the local environment. Further details will be found in [5].

To have a better understanding of the daily variability in the gamma radiation and PG time series, Figure 1 depicts the hourly medians of the original 1-minute time series only under FW conditions (a total of 27 days) that occurred during the whole period of observation. FW days are selected based on locally undisturbed daily solar radiation curves (not shown). This is because meteorological events like shower-clouds, fogs, strong winds and thunderstorms (which happened between 23 and 25 June) perturb dramatically the PG and shadow any possible relation with radon. In addition, one FW day, 13th June, was removed from the analysis as a PG outlier. For spectral analysis, it was used the Lomb-Scargle periodogram (LSP), which is developed for time series with irregular sampling intervals, as it is the case of the PG restricted to FW days. For that reason, LSP has been used in other PG studies [6-7] For a better view of the daily variability, a scatter plot between the daily medians of both variables is obtained along with their respective horizontal and vertical error bars (based on the Q1 and Q3 quartiles of each daily distribution).

3. Analysis and discussion

On one hand, the gamma time series shows high variability at different time scales with irregular daily cycles. This is expected since such type of complex behavior has also been found on a wide range of other locations and under diverse environmental conditions [8-11]. These patterns may likely result from nonlinear interaction of local environmental and meteorological effects whose interaction is still difficult to assess and not well known [12]. On the other hand, using only the FW days, the PG has a well-defined daily cycle (not observed in the gamma time series). This suggests that there does not seem to exist a direct relation between gamma and PG at the daily scale.

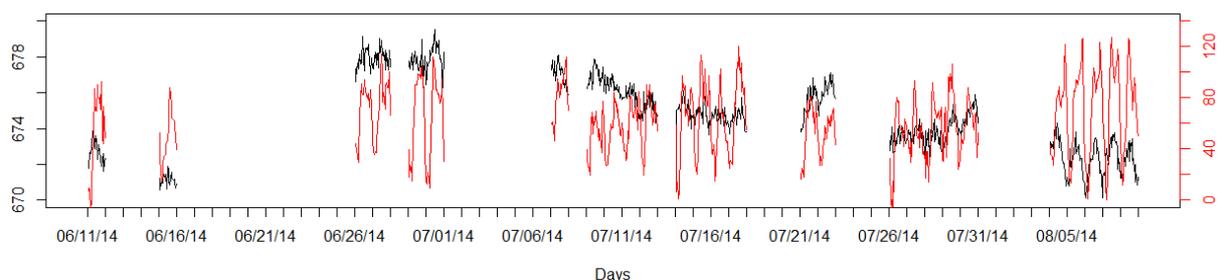


Figure 1. Hourly medians for the gamma (black) in counts/100 and the PG (red) in V/m. Only FW days, 11th June to 8th August 2014.

In fact, a closer look into the daily variability for the gamma and PG hourly time series is depicted in Figure 2. Here, the daily hourly medians are calculated by applying medians to each hour of the day for all the FW days. The distribution is uniform for the gamma (Figure 2, left), whereas the corresponding daily maximum and minimum is difficult to assess, but they seem to occur during the afternoon and during the night, respectively. As opposed to these, the PG hourly medians (Figure 2, right) show well-distributed daily pattern with the daily minimum in the early morning and daily maximum in the middle of the day, similar to the Carnegie behavior [13].

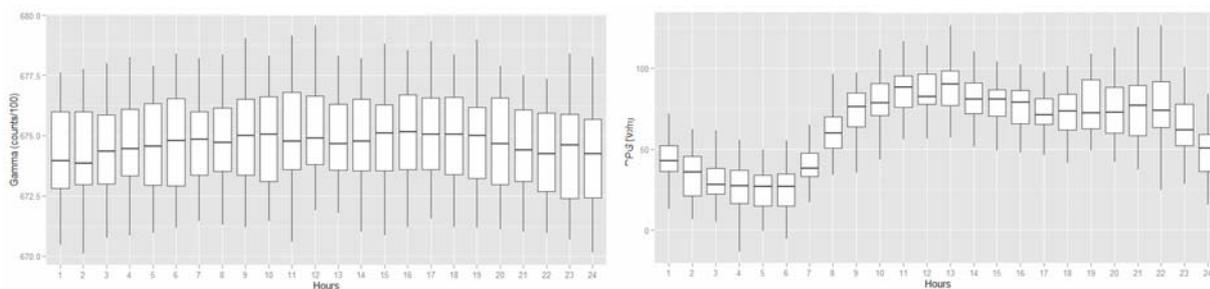


Figure 2. Boxplots of hourly medians for the Gamma (left) and PG (right) daily cycles. Only FW days, 11th June to 8th August 2014.

The energy of the depicted cycles can be seen in detail in Figure 3, where the LSP is applied to both series. Gamma radiation shows higher energies in the high period range (above 1 day) and reveals a flat response to periods below half-day. It is also observed a very weak daily period. This behavior is opposed to the PG case. The PG has a notorious and energetic daily peak, as expected [6]. For periods above 1 day the spectrum tends to flatten. A semi-diurnal cycle is also observed in the PG data, with a clear second energetic peak for period of 0.5 (two cycles per day) and a decreasing trend below this period. The cycles observed in the PG are a result of the influence of the global atmospheric electrical circuit [13] and local influences, while the physical mechanisms behind the gamma cycles are conventionally ascribed to meteorological factors such as barometric pressure and temperature [10]. It is evident that there is no spectral relation between the gamma and the PG data.

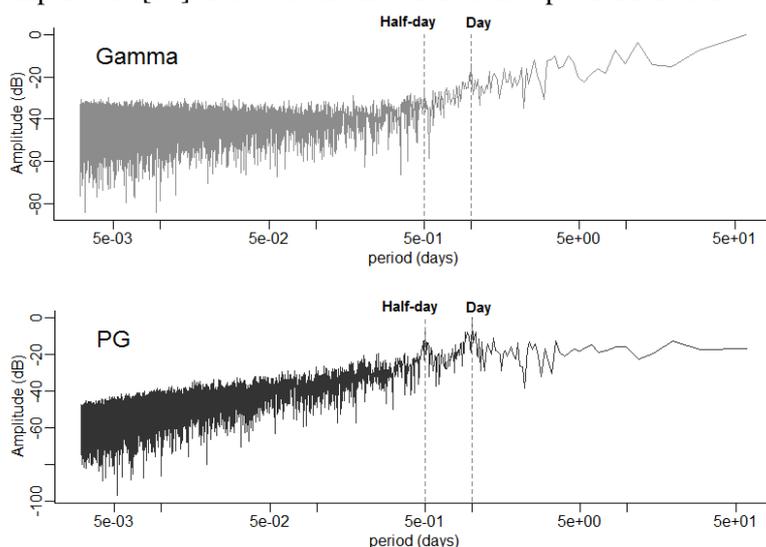


Figure 3. Lomb-Scargle Periodograms for the Gamma (top) and PG (bottom) hourly time series. Only FW days, 11th June to 8th August 2014.

Furthermore, a scatterplot (Figure 4) illustrates a uniform distribution of the daily medians (obtained through the respective hourly medians, in order to reduce the high frequencies observed previously) of the PG and gamma radiation, indicating that there is no clear correlation between variables in the

present data. The high daily distribution of the PG is reflected by the vertical error bars (in grey) length that are longer than the gamma error bars (in black) which show almost the same length due to the very low change of radon concentration during the day.

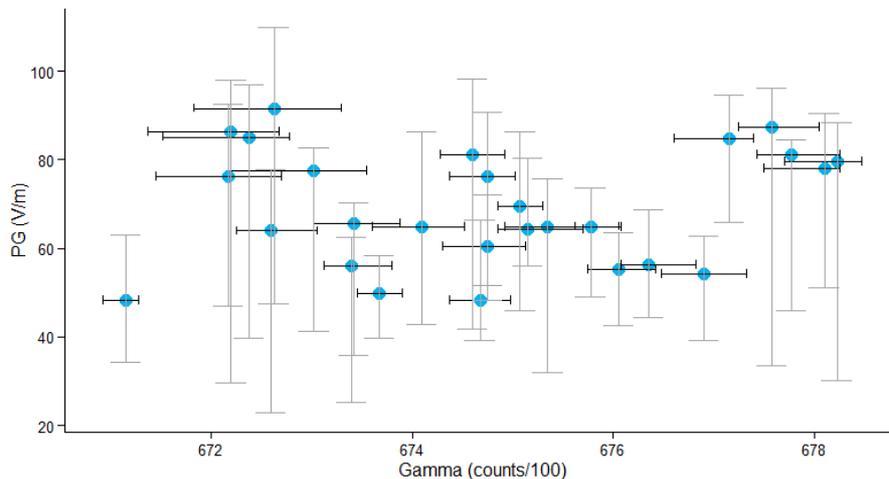


Figure 4. Scatterplot for the Gamma and PG daily medians together with their respective error bars. Grey error bars are for PG and black error bars are for the gamma. Only FW days, 11th June to 8th August 2014.

4. Final remarks

Gamma radiation showed low frequency variability contrary to PG. The results of this study point towards no obvious short-term relation between soil-emitted gamma radiation and the local potential gradient at the Amieira site. This necessarily implies future work such as performing new measurements in radon rich regions (e.g., granitic areas), acquisition of longer recording periods for long-term tendencies, measurement of airborne radon levels (which should have higher variability during the day than soil radon concentration), and measurement of air ions.

Acknowledgments

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