Local variation of the superficial atmospheric electricity activity in a tropical region

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Abstract. A study of the atmospheric surface electrical activity in the Maracay city (10°14'59.1"N 67°37'20.6"W 436masl) is performed, through the analysis of the Carnegie curve. We present the methodological construction of the Field Mill, for the measurement of the electric field atmospheric, and a counter of atmospheric ions, based on the capacitor Gerdien. We shown that the local heating due to convective movement during the morning could change the concentration of ions, and subsequently, produce a second local minimum in the curve of the local electric field, this second minimum is not a feature of the Carnegie curve. We conclude that the curve of local variation of the superficial atmospheric electricity activity, under conditions of clear skies and no clouds, for the tropical region, as in the Maracay city, is functionally similar to Carnegie curve.

Keywords: Atmospheric electricity, Carnegie curve, Meteorological instruments

1. Introduction

Exist an atmospheric electric field perpendicular to the surface, and inherently negative since his sense is penetrating to earth surface. That is still present, even in fair weather conditions. This field has a variation of about 100V / m for every meter you climb (Rycroft et al, 2008), besides having local and temporal variations (Harrison, 2013). And is framed in the construct the telluric capacitor about of the global electric circuit, proposed by Wilson in 1921, in which the Earth is a giant spherical capacitor consisting of an insulating material (ground) coated by a dielectric (the troposphere), with a conductive layer that covers it: the ionosphere, (Siingha et al 2009).

The temporal variation of the atmospheric electric field versus universal time is called Carnegie curve. And representing the average of thousands of measurements of the atmospheric electric field of the earth, under fair weather on the world's oceans, where it is assumed not exist contamination, due to aerosols. In equation 1 we present the adjustment in Fourier series, made by the Carnegie institute to estimate the relative contribution of the 12 and 24h of the diurnal cycle in the potential gradient (Harrison 2013).

$$V(t) = A_0 + A_1 sin\left(\frac{t}{24}360\,^{\circ} + \varphi_1\right) + A_2\left(\frac{2t}{24}360\,^{\circ} + \varphi_2\right) + A_3\left(\frac{3t}{24}360\,^{\circ} + \varphi_3\right) + A_4\left(\frac{4t}{24}360\,^{\circ} + \varphi_4\right) \quad (1)$$

Characterize the temporal variability of atmospheric electric field is important in the study of electrical conduits, telecommunications and electrometeors studying (lightning). Recent researches (Kamogawa et al. 2014), show evidence that the atmospheric electric field is maximum when the concentration of aerosol is maximized. We performed similar measurements, but contrasting the atmospheric electric field with ions, instead of the aerosol particles. Our goal is to quantify the atmospheric electric field at surface level, for obtain the local Carnegie curve for Maracay city. We will present details of the manufactured instruments, such as the field mill and atmospheric ion counter, exposed in section 2. Results of the measurements are presented in section 3 analyzing the relationship between atmospheric ions, and atmospheric electric field. Finally in section 4, we present brief conclusions.

2 Measurements and equipment

Data were collected on land, specifically at coordinates 10°14'59.1"N 67°37'20.6"W 436masl. The location was electrically isolated: nearby buildings do not exceed five meters in height, a twenty meters around. The measurements were performed only in fair weather conditions with clear sky, no clouds or nearby thunderstorms.

For electric field measurement, was used a Field Mill of own manufacturing. The for prototype is based in a model of Wilsons's plates, where the period of current measured is equal to the half period of the engine that used to move the lampshade plate. In figure 1 we show details of the Field Mill. To measure the signal of sensor plate, was used the circuit exposed in figure 2 (top). This is a differential amplifier. And for established the correct phase for atmospherically electric field measured, we use an amplifier by phase controlled, show in figure 2 (bottom). For his correct use, it is equip has been pointed to Earth surface and connected to ground. Because, this equip measured the potential difference between equipotential surfaces. If placed pointing to the sky, all equipotential surfaces would be measured, causing a measurement mistake. For data collection, the field mill was placed at a fixed height of 1m from ground surface.

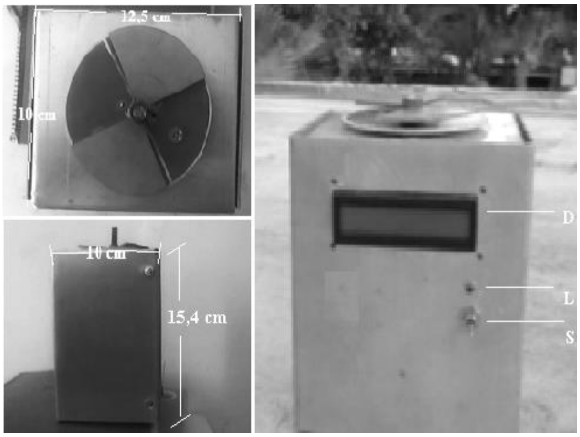

Fig. 1. Field mill used to measurement of atmospheric electric field. D: Display LCD, L: LED diode start indicator, S: Switch on/of.

For measurements of atmospheric ions was used a counter ions, of own manufacturing, which is based in Gerdien condenser. In figure 3, we present the circuit of this equipment, and in figure 4, a picture of this finished. For correct use of this device should be placed on the ground at a distance of 1 m in height and before any measurement, press the download button until we obtain zero in voltage reading.

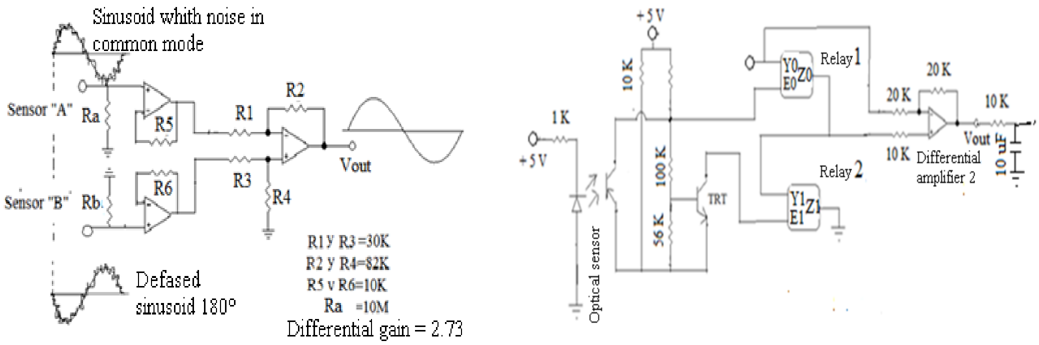

Fig. 2. Differential amplifier used to manufacture the field mill (left). Rectifier by phase controlled used to manufacture the field mill (right).

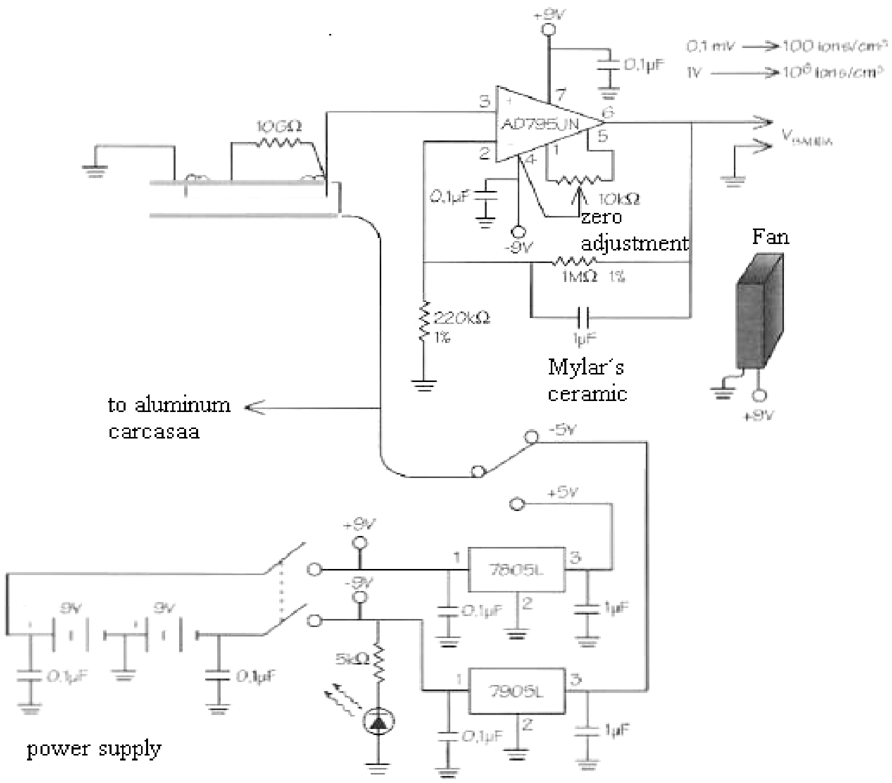

Fig. 3. Electric circuit of the counter ions.

Collecting data on days 6 to 8 hours in diurnal and nocturnal. The sampling process began in December 2013 and ended in May 2014. The results will be presented in the next section, starting with the Carnegie curve, through the distribution of atmospheric ions, and culminating with the correlation found between the local distribution of atmospheric ions and atmospheric electric field.

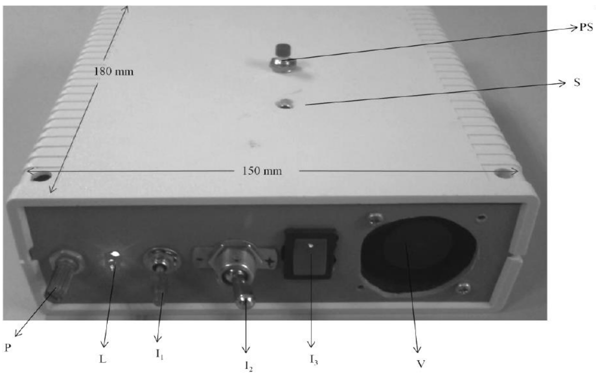

Fig. 4. Ions counter, P: zero adjustment, L: power LED, I_1: power switch, I_2: positive and negative switch, I_3: fan switch, V: fan, S: voltage output, PS: reset button.

3 Results and discussions

In figure 5 we present the diurnal variation (in universal time) average atmospheric electric field. Error bars on the Y axis are from the calculated error for the Field Mill during calibration process, the error bars in the X axis is very small so they are not noticeable on the graph. The solid line connecting points is the experimental fit made with the equation 1 for the amplitudes and phase shift angles.

The adjustment was performed using the software QtiPlot. In equation 2, it`s shown the value of the coefficients in units of the volt/meter. We will call "curve of the Electrical atmospheric variation for the Maracay City", by analogies to the Carnegie curve.

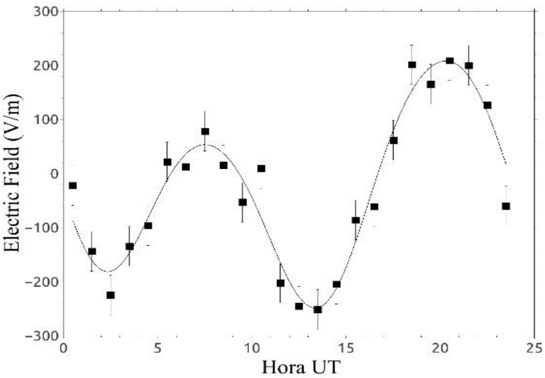

Fig. 5. Average atmospheric electric field values (squares). The solid line is the data fit realized with the equation 1.

$$V(t) = -28.5 - 93.4sin\left(\frac{t}{24}360^{\circ} - 51^{\circ}\right) - 168sin\left(\frac{2t}{24}360^{\circ} - 33.7^{\circ}\right) - 9.6sin\left(\frac{3t}{24}360^{\circ} - 56.7^{\circ}\right) - 11.4sin\left(\frac{4t}{24}360^{\circ} - 16.7^{\circ}\right)\left[\frac{V}{m}\right] \quad (2)$$

In figure 6 we present the super position of both. The dotted line is the graphical representation of equation 2 which is equivalent to the Carnegie curve for the Maracay city, the solid line represents the equation 1 for annual values (Harrison, 2013) which is equivalent to Carnegie World curve. Note that appears a second minimum as a global minimum not characteristic in the Carnegie Curve. We will see in the development of this paper, that there is a correlation between the electric field and ion atmospheric, so that the explanation.

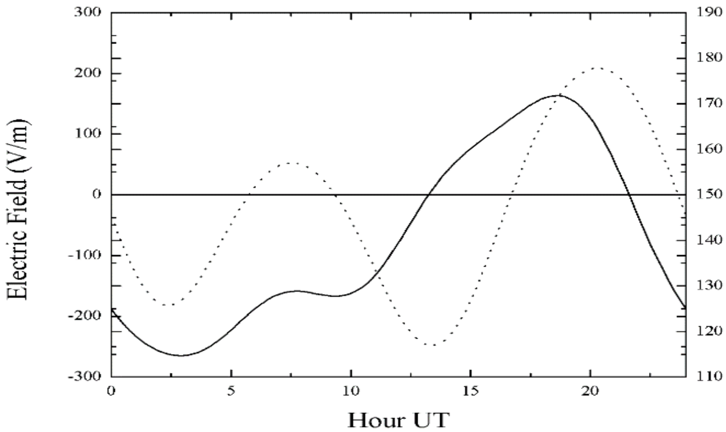

Fig. 6. Average potential gradient annual for the world (solid line). Average potential gradient for the Maracay City from December to May (dotted line). The right axis correspond to the solid line and left line.

We derived both curves to study displacement between maximum and minimum, the result is presented in Figure 7. Note that, the local time is UT – 4:32 hours, but the HLV (Legal Hour of Venezuela) is only HLV= UT-4:30

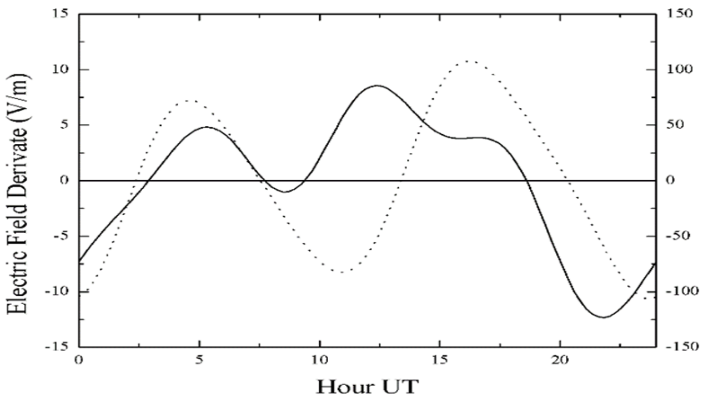

Fig. 7. Temporal derivates of the Carnegie world curve (solid line) and the Maracay city Carnegie curve (dotted line). The right axis corresponds to the solid line and left axis to the dotted line.

The unique discrepancy between curves is the displacement observed from 10 UT, to grow and shrink at the same intervals. Then, we can see that the most relevant time difference between the world average and the average for the Maracay city occurs for the second minimum, with four hours apart. The explanation for this discrepancy would be the atmospheric ions.

In figure 8 we present the diurnal variation of positive and negative atmospheric ions. The error bars in the Y-axis are from the error calculated during the calibration process for the counter-ion. The error bars on the X-axis are small thus not seen in the graphic. The solid line through the points is the adjustment made with the software Qtiplot using equation 1. Fittings are presented in equations 3 (Negative Ion) and 4 (Positive Ions) respectively.

$$Ions- = \left\{7.2 + 1.5sin\left(\frac{t}{24}360^{\circ} + 142.2^{\circ}\right) - 0.2sin\left(\frac{2t}{24}360^{\circ} - 11.4^{\circ}\right) + 0.4sin\left(\frac{3t}{24}360^{\circ} + 11.4^{\circ}\right) - 0.3sin\left(\frac{4t}{24}360^{\circ} + 17.1^{\circ}\right)\right\}\left[\frac{10^3 particles}{cm^3}\right] \quad (3)$$

$$Ions+ = \left\{6.9 + 2.3sin\left(\frac{t}{24}360^{\circ} + 143.2^{\circ}\right) + 0.6sin\left(\frac{2t}{24}360^{\circ} - 34.3^{\circ}\right) - 0.1sin\left(\frac{3t}{24}360^{\circ} + 91.6^{\circ}\right) - 0.3sin\left(\frac{4t}{24}360^{\circ} + 34.3^{\circ}\right)\right\}\left[\frac{10^3 particles}{cm^3}\right] \quad (4)$$

In figure 9 are presented the correlation plots between atmospheric ions and the atmospheric electrical field. The solid line represents the linear fit realized to the data. The Pearson correlation is 0.85 for positive ions and 0.83 for negative ions, showing a high correlation between electric field and atmospheric ions. This value of the correlation coefficient is obtained for large concentrations of ions, upper to 6500 ions per cubic centimeter, equivalent to 2.1043×10^{-14} C in the volume between electrodes of the Mill Field. Concentrations below to this value, is outside of the threshold detection of the Mill Field. However, although the correlation is high, this does not imply causality, only allows assumptions about the relationship between these two variables.

Already shown that there correlation between the potential gradient and atmospheric ions, explains the no characteristic extreme value of the second minimum in the Carnegie curve to the city of Maracay, and that it occurs between 10 (5:30 local time) and 15 (10:30 local time) UT-hour period in which develops the "daytime heating" . Consequently, the second minimum observed in the Carnegie curve would be caused by a heating local factor, due to solar irradiance and convection air movement.

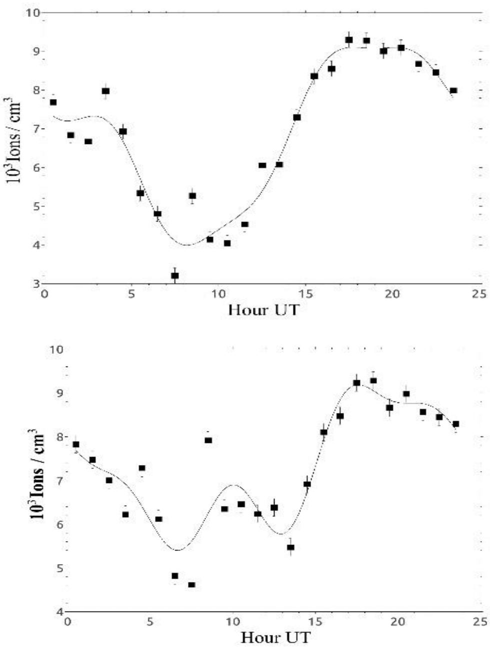

Fig. 8. Variation for the negative atmospheric ions average (Top). Variation for the positive atmospherics ions average (Botton).

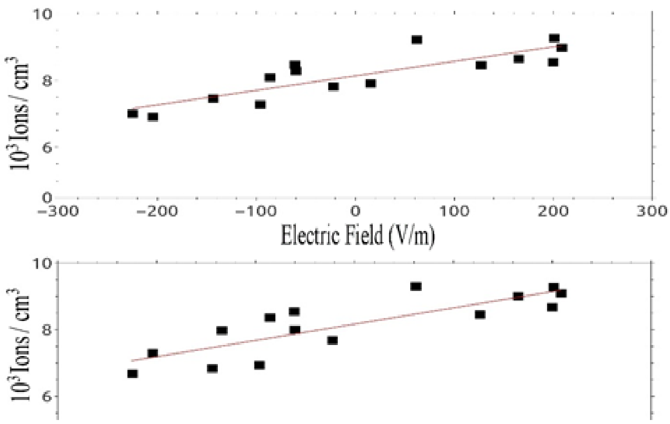

Fig. 9. Concentrations of the Atmospheric ions versus local atmospheric electric field. Top: negative ions, bottom positive ions.

4. Conclusions

We found that the local variation of the superficial atmospheric electricity activity; under conditions of clear skies and no clouds; for the tropical region, as in the Maracay city (see figure 6 and eq. 2), and conclude that is functionally similar to Carnegie curve. The local heating due to convective movement during the morning could change the concentration of ions, and subsequently, produce a second local minimum that is not a typical feature. The high correlation found between the temporal variation of the concentration of atmospheric ions, and the atmospheric potential gradient could corroborate this assumption. We have also found that systematic measures the field mill and the counter ion to characterize roughly the local variability of the atmospheric electric field surface, with temporal variation comparable to those made in the open ocean on-board R/V Hakuho Maru (Kamogawa et al 2014).

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