A New South America Electric Field Monitor Network

J.-P. Raulin[1], J. Tacza[1], E. Macotela[1], G. Fernandez[2]

[1]Centro de Radio Astronomia e Astrofísica Mackenzie(CRAAM), Escola de Engenharia, Universidade Presbiteriana Mackenzie, Brazil;

[2] Complejo Astronómico El Leoncito, CASLEO, San Juan, Argentina;

E mail (raulin@craam.mackenzie.br).

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Abstract: In this paper we present the installation and operation of a new network of sensors located in South America in order to monitor the atmospheric electric field. The main goals of such new instrumental facility is to provide continuous measurements of the diurnal variations of the atmospheric electric field during fair weather undisturbed conditions, and to study its variations in time and space, and as a function of the season and the solar activity conditions. Of particular interest will be the transient variations and their relation with seismic activity occurrence in the region. Finally, by using this new network, we also pretend to better understand the relation between changes in the electrical properties of the atmosphere and excesses in the measurements of the cosmic ray flux.

Keywords: Atmospheric electric field, Carnegie curve, Global electric circuit, cosmic rays, seismic activity.

Introduction

The Global Atmospheric Electric Circuit (GAEC) links charge separation in disturbed weather regions with current flows in fair weather regions. The circuit is closed at both ends by two highly conducting layers, the Earth's surface and the ionosphere. In the absence of any power supply to maintain the ~ 250 kV electric potential gradient of the ionosphere relative to the Earth, the currents flowing in the fair weather regions of the globe should vanish after few tens of minutes. Wilson (1920) proposed the thunderstorm and electric shower cloud generator hypothesis where charged particles are transferred from the bottom of thunder clouds to the surface of the Earth and from the top of the thunder clouds to the ionosphere. Indeed, there is a close correspondence between the Carnegie curve representing the daily variations of the electrical potential gradient measured in fair weather conditions over the oceans, and the global diurnal variation of thunderstorm and electrical showers clouds occurrence (Liu et al., 2010; Harrison, 2013). Rycroft et al. (2000) have studied how the GAEC is affected by solar, geomagnetic and cosmic transients, as well as how it is influenced by aerosols and pollution.

The GAEC has also been studied to look for short-term precursors of seismic activity. The main reason for that is that radon emanation excesses associated in time and space with seismic events is nowadays an undisputed observational fact (see e.g. Pulinets and Boyarchuk, 2004, Chapter 1; Harrison et al., 2010; Goesh et al. 2009). Radon decay provides the greatest contribution to the atmospheric ionization in the near-Earth surface, and, therefore, changes of radon concentration will affect the electrical conductivity which in turn will produce changes on the measured atmospheric electric field. However, the latter is difficult to observe because of the great variety of phenomena and perturbations that can affect its value, like thunderstorms, fog, dust, strong winds, rain precipitation, snow, aerosols and other air pollution. Therefore, a necessary condition to look for seismic precursor by studying the behaviour of the atmospheric electric field is that reliable fair weather diurnal variations can be obtained.

Finally, transient variations of the intensity of the atmospheric electric field have also been systematically reported in association with temporal variations of the secondary cosmic ray flux measured at the same location (De Mendonça et al., 2010). Such observations open new possibilities for a better understanding of the relationship between extreme variations of the electrical properties of the atmosphere as during lightning periods, and local excesses of the cosmic ray flux.

Objectives

The main objectives of the newly installed South America Network for Atmospheric Electric Field Monitoring are: (i) to obtain reliable Carnegie-like diurnal curves of the atmospheric electric field; (ii) to study how the electrical properties of the atmosphere vary in space within the region, and as a function of the season and the solar activity condition; (iii) to look for departures and discrepancies from the diurnal variation curves and associated with seismic activity, which is known to be important in the region; (iv) to study how large and fast changes of the atmospheric electric field, and cosmic ray flux transient variations are related.

Instrumentation and data calibration

In Figure 1 we show the location of the atmospheric electric field sensors (EFM) already installed by December of 2012. We also show the places where new EFM detectors will be installed.

Figure 2 shows the basic principles of the EFM operation. A current is set from the ground through the

100 kΩ resistor when the sense electrode is exposed to the atmospheric electric field. When the sense electrode is not anymore exposed to the electric field the same current flows to the ground through the same resistor. The electrical potential drop through the resistor is then proportional to the intensity of the atmospheric electric field. A second resistor in parallel allows changing the sensitivity of the measurement in order to avoid saturation due to high electric field intensities, typically > 20 kV/m, during stormy or lightning periods.

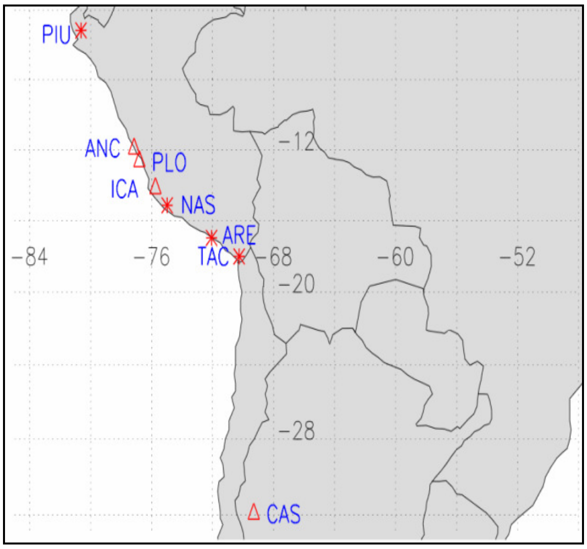

Figure 1: EFM sensors already installed (triangles), and future locations for new sensors (stars).

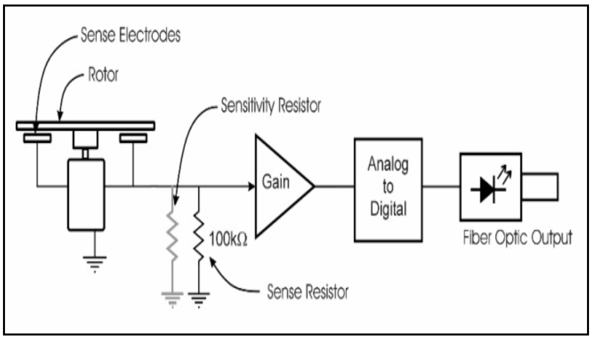

Figure 2:Block diagram for EFM sensor (from Boltek corporation EFM100-1000120-050205).

Figure 3 illustrates the final position of the EFM sensor at ICA University (Peru), at a height of about 50 cm above the ground. Under this disposition the measured atmospheric electric field does not correspond to the fair weather electric field value we are interested in. The measurement needs a correcting factor for the electric field enhancement which occurs when objects are mounted above the ground.

Figure 3: Final position of the EFM sensor installed at ICA University.

This process, known as calibration, is illustrated in Figure 4 where we have correlated the measurements obtained simultaneously by two sensors, one located at ground level and the other one at its permanent position above the ground.

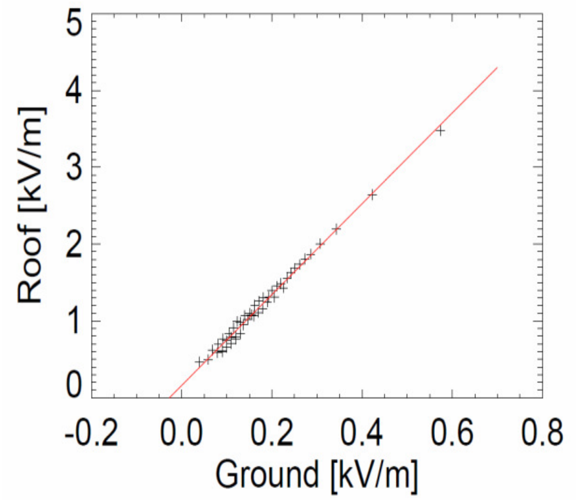

Figure 4: Correlation of EFM measurements obtained at PLO at ground level and on the roof of the operation building.

First Results

Preliminary results are shown in Figures 5a and 5b for the sensors located at CASLEO (CAS) and Punta Lobos (PLO), respectively. The curves represent daily variations of the atmospheric electric field based on a monthly average during the months of May of 2008 at CAS, and July 2012 at PLO.

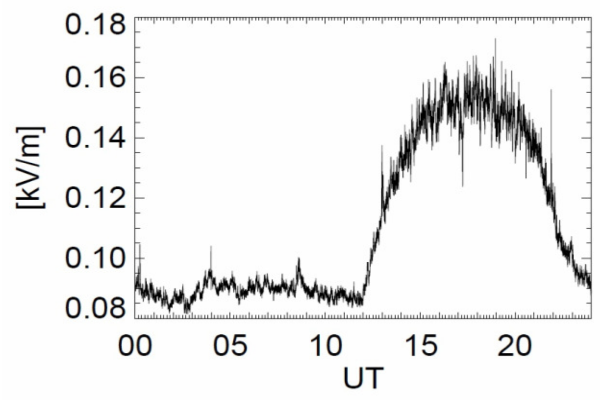

Figure 5a: Non calibrated mean daily variation of the atmospheric electric field measured at CASLEO .

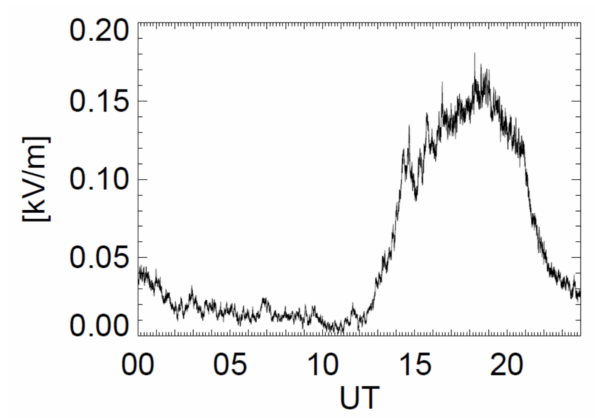

Figure 5b: Calibrated mean daily variation of the atmospheric electric field measured at PLO.

The former are still non calibrated data, for which the maximum has been normalized to 0.15 kV/m. It is important to note that for each curve and for the months considered, more than 60 % of the daily curves were used. This indicates that one can obtain at both locations very reliable curves of the mean daily variations of the atmospheric electric field under fair weather conditions. The remaining 40 % of the daily curves were not used because they clearly included transient variations of the electric field due to electrically charged or thunderstorm clouds and/or lightning discharges. Similar results were obtained at the other bases in ICA and Ancón (ANC). The fact that one can recover significant and reliable mean daily variation curves of the fair weather atmospheric electric field will be helpful to study how the GEC behaves as a function of sensor's location, the seasons and the solar activity cycle. Such template daily variations will be also important to identify any decrease of the near-surface electric field due to an increase of radon release during high seismic activity (Pierce,1976; Silva et.al., 2012).

A few numbers of events showing a good correspondence between transient variations of the atmospheric electric field and cosmic ray flux increases detected by the CARPET at CASLEO have been observed so far (De Mendonça et al., 2010).

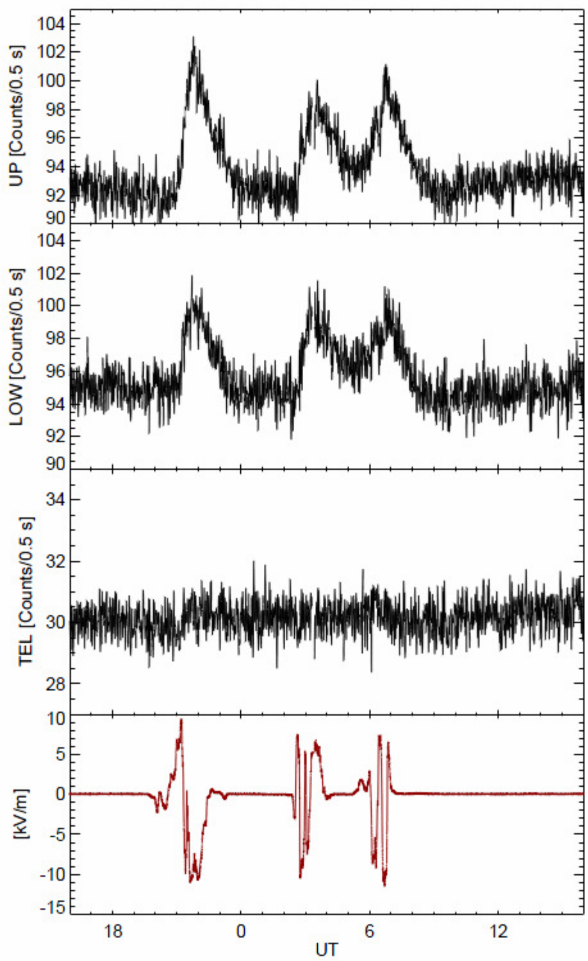

Figure 6a: Transient atmospheric electric field variations associated with secondary cosmic rays flux increases in the LOW and UP channels of the CARPET sensor.

The CARPET cosmic rays sensor is a charged particles detector and its performances have been described by De Mendonça et al. (2010). LOW and UP channels of the CARPET detector are dominated by electrons with energies > 0.2 MeV, protons with energies > 5 MeV and γ-rays with energies > 20 keV (detected with an efficiency of less than 1%). TEL channel is dominated by electrons with energies > 5 MeV, protons with energies > 30 MeV and muons with energies > 20 MeV. Two examples of such association are shown in Figures 6a and 6b. A clear one-to-one temporal association is observed between atmospheric electric field variations and increases observed in the low energy channels of the CARPET (Fig. 6a). Much stronger electric field changes also appear in close association with variations in the high energy channel of the CARPET (Fig. 6b). These two examples suggest a close relationship between both phenomena, whether the possibility of having secondary electrons being accelerated by the atmospheric electric field, or the increase of the cosmic ray flux setting favourable conditions for changes of the atmospheric electric field .

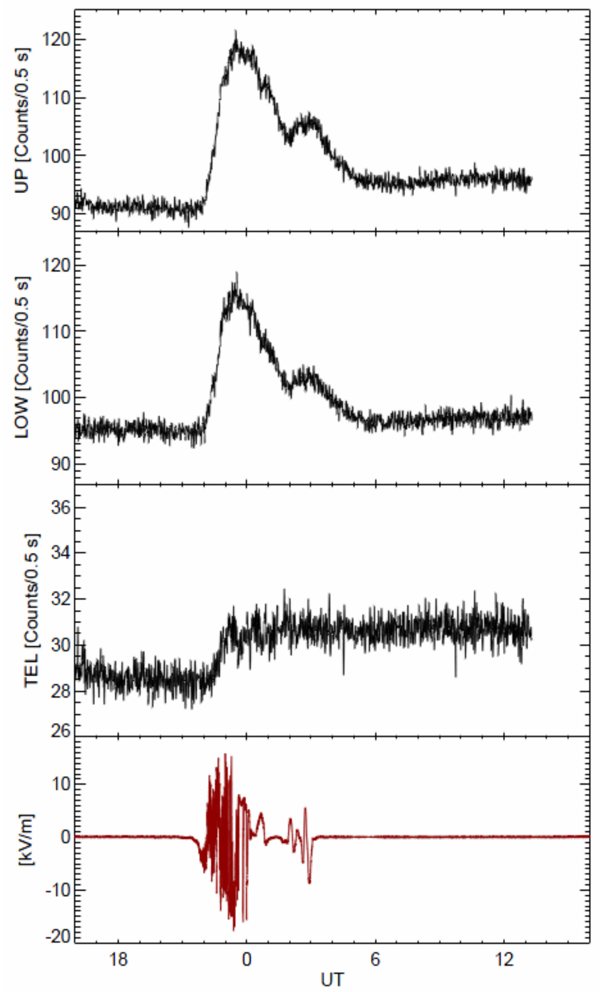

Figure 6b: Transient atmospheric electric field variations associated with secondary cosmic rays flux increases in all channels of the CARPET sensor. Note between 22:00 and 23:30 UT faster electric field variations due to presence of lightning.

Conclusions

In this study we have presented a new instrumental facility in the South America region to monitor the atmospheric electric field. Composed of four stations at the present time, we plan to have a few more bases installed in 2013. Preliminary results indicated the possibility of providing reliable diurnal variation curves of the fair weather atmospheric electric field. This will be important to assess how the properties of the GAEC vary as a function of time and as a function of solar activity conditions. Departures from fair weather diurnal variations of the atmospheric electric field will be used to look for short-term precursors of enhanced seismic activity in the region. Intense variations of the atmospheric electric field will be also studied in relation to fast changes of the local cosmic ray flux.

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