

Preliminary findings of surface fair-weather electric field trends over small tropical island station, Suva, Fiji

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1 INTRODUCTION

The electrical properties of the Earth's atmosphere have been continually investigated since late eighteenth century, due to its relevance to local climate system and reliance on global solar terrestrial activities. The global electrical measurements are gaining renewed prominence since they are found to be a more effective and efficient means of monitoring global warming trends (Williams *et al.* 2003). The surface potential gradient (PG) or electric field was found to be positively correlated to the aerosol number concentration (Jayaratne and Verma 2004). Surface PG measurements have often proved as the most frequently used (Anderson 1967) and reliable technique to study atmospheric electricity, be it global, regional or local (Latha 2003). Systematic analysis of surface fair-weather PG recorded every 10 s over a period of 13 months (June '05–July '06) at a small tropical island station, Suva (18.08 °S, 178.45 °E), Fiji, is presented. The 24-hour cycle had distinct bimodal oscillation in PG with peaks in the morning (~08 hrs LT) and late in the evening (21 hrs LT). To infer any relationship between the regional thunderstorm activity to the local PG, diurnal variation of regional (0 – 60 °S and 100 °E – 160 °W) lightning activity obtained from World-Wide Lightning Location Network (WWLLN) archives, for the fair-weather days observed during the period of study were analyzed. The lightning showed peak activity at ~20 hrs LT.

A popular model for understanding the global electrical environment assumes two spherical equipotential regions, the Earth's surface (negative) and a highly conducting positively charged electrosphere – *equalizing layer* assumed to be coinciding with the lower layer of the ionosphere, connected together by weakly conducting lower and middle atmosphere (Volland 1984). Charges in the atmosphere arise from the imbalance between the production of ions, by radioactivity and cosmic rays, and the loss by recombination and attachment to large particles such as smoke, water spray. The potential difference between the electrosphere and the Earth's surface gives rise to a vertical electric field within the Earth's atmosphere.

Under fair-weather conditions, the equalizing layer has an average potential ranging between 180 – 400 kV with respect to ground (Volland 1984). Wilson (1920) hypothesized that despite the charge neutralization, the potential difference is maintained essentially by thunderstorm activity. Based on this assumption, the negative charges transferred to the Earth and the positive charges transferred to the electrosphere create an electric field pointing towards the Earth. The thunderstorms, therefore, complete the global electrical circuit. Over land, the thunderstorm rate is ~10 times more than that over sea (Williams and Heckman 1993).

Since the Northern Hemisphere has comparatively larger landmass, its thunderstorm activity outweighs that in the Southern Hemisphere, hence it is assumed to have a dominant effect on global electrical circuit. Long term measurement of PG over oceans features a global maximum around 19 hrs UT, this pattern is known as the Carnegie Curve, named after the sailing vessel on which the original measurements were made (Israel 1973). Anderson (1967) quoted that the global diurnal PG cycle closely follows the variations in global thunderstorm activity which was discovered by Whipple (1929) by summing the diurnal variations in thunderstorm activity over Africa, Australia and America, and the pattern followed the Carnegie curve.

2 INSTRUMENTATION

The experimental site is the University of the South Pacific (USP) and is ~1 km from the coastline and ~2 m above the sea level. There are no sources of direct pollution in the vicinity and the nearest industrial area is located ~4 km inland. Since 2003, USP is a member of the WWLLN and the data collected at this site are also used for global lightning location. An electrostatic field meter (JCI 131) which operates on the concept of field mills was used to record the Earth's electric field. The JCI 131 is specifically designed to provide precise, high resolution, low noise (less than 1 Vm⁻¹) electric field data and is capable of continuous recording. It produces an analog output signal proportional to the incident electric field at the sensing aperture. The device was mounted on a vertical galvanized iron pole of height 2 m, over level ground and ~25 m away from nearby trees, buildings and power lines. A thick insulator separated the field mill from its support. The JCI 131 output was interfaced to a PC based data acquisition system.

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3 RESULTS AND ANALYSIS

On most days, the site was covered, in full or part, with cirrus/cirrostratus clouds. To classify the day as a fair-weather day, the solar radiation was also continuously monitored. At the measurement site, a smooth parabolic curve for solar radiation having a peak greater 800 Wm^{-2} with no rainfall was classified as a fair-weather day. Based on this classification, 63 days were considered as fair-weather days during the period of study. On a cloudy day, with high lightning activity in the overcast clouds, the PG can reverse its direction due to the highly negative lower base of the cloud, however, on a fair-weather day, the PG would remain positive. Closer analysis of the data showed that at times the potential at the sensing aperture suddenly went more than 10 kV. This was attributed to foreign particles (pieces of grass, leaves etc.) coming in contact with the sensing aperture of the field mill. The data were further classified similar to the '0b' days as proposed by Harrison (2003) where one minute average of PG lies in the range of 0 - 1000 V m^{-1} . The diurnal variation of the average hourly PG is shown in Figure 1. Also included in the figure is the global Carnegie curve. The measured average PG was $\sim 143 \text{ V m}^{-1}$ and is comparable with the average Carnegie variation of 129 V m^{-1} . The variation of PG in Figure 1 shows double oscillation with peaks around 10 and 21 hrs UT. Despite the global origin of atmospheric electric fields, its magnitude close to the surface may be strongly mediated by local meteorological parameters such as cloud cover, wind speed, humidity. Various earlier studies reveal high divergence of PG from Carnegie trends, which are mainly due to the local influences of turbulence, weather, smoke, aerosols and other anthropogenic factors (Israelsson and Tammert 2001; Latha 2003; Harrison 2004). Relatively small ions in the atmosphere originate mainly from the interaction of cosmic rays with air molecules and by natural radioactivity. The concentration of these small ions decreases with altitude, near sea level it is between ~ 500 to 600 cm^{-3} (Reiter 1992). In regions far away from thunderstorm areas, a downward directed ionic current density of the order $\sim 3 \text{ pAm}^{-2}$ flows between the electrosphere and ground (Volland 1984). The Carnegie

curve was measured over oceans where the effect of particulate matter is negligible. Over land, pollutants in the form of particulate matter play an important role in determining the PG. The mobile charges and ions adhere to the relatively heavy particulate matter in the atmosphere decreasing the electrical conductivity of the atmosphere. Thus to maintain the same current density, the potential at that point in the atmosphere increases resulting in the increase in the PG (Volland 1984). Our measurements were over land hence may be a slight increase in the average PG value. Jayaratne and Verma (2004) showed that the Earth's fair weather electric field increases with an increase in the aerosol particles concentration in the environment. In the bimodal variation Israel (1973) noted that one of the modes coincides with the maximum global thunderstorm activity (~ 19 hrs UT) while the other occurs in the late afternoon local time. The morning peak (20 hrs UT) is the more intense of the two peaks. The morning (at 08 hrs LT) maximum and noontime (12-17 hrs LT) minimum at the site coincide well with those variations on the Carnegie curve. The morning oscillation, which is frequently referred to as the *sunrise effect* has been elucidated by many researchers as a function of variations in aerosol concentration (Harrison 2004; Dhanorkar and Kamra 1994). It predominantly occurs during summer over most of the temperate regions. Marshall *et al.* (1999) explained that if the measurement site is close to water bodies *viz* ocean, sea, river then the sunrise effect could be dominant. Our measurement site is close to the sea, hence the observed dominance of the morning maximum.

Lightning data for the region ($0 - 60^\circ \text{S}$ and $100^\circ \text{E} - 160^\circ \text{W}$) obtained from WWLLN were analyzed for the 63 fair-weather days observed during the period of study and the diurnal pattern for these days is also shown in Figure 1. The regional thunderstorm activity was low around the dominant morning peak in PG. Peak thunderstorm activity was observed around ~ 21 hrs (LT) which was close to the time of the secondary maximum in PG ~ 21 hrs LT at the site. However, the contribution by regional thunderstorm activity must be explored further.

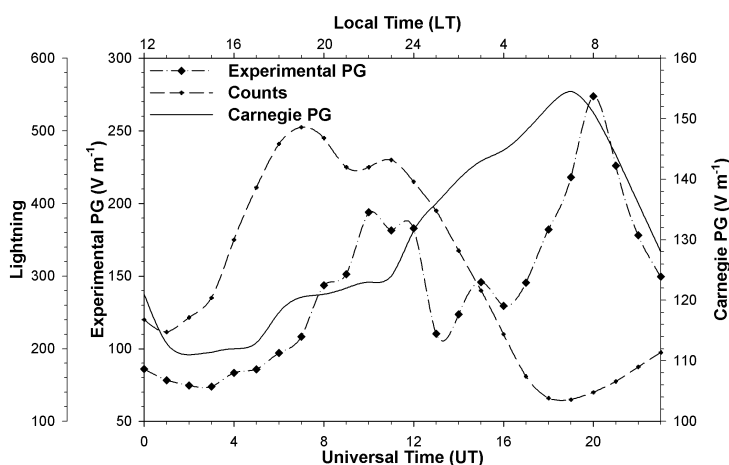


Figure 1. Diurnal variation of measured PG, lightning counts and Carnegie PG (adopted from Harrison (2003))

4 CONCLUSION

During the period of study, 63 days were classified as fair-weather days. The trend of diurnal variation showed distinct double oscillation in PG with peaks at ~ 08 hrs LT and at ~ 22 hrs LT. The intense morning maxima and the noontime minima coincide well with those variations on the Carnegie curve. The lightning during the days considered showed peak activity at ~ 21 hrs LT.

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