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Research Article

Orographic features of global atmospheric fair weather electrical parameters over different places of Sri Lanka

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Abstract

Altitude variation of fair weather atmospheric electrical parameters such as atmospheric conductivity, air-earth current density, electric field, and atmospheric potential have been analyzed over 210 different places of Sri Lanka when the fair weather conditions were being existed. Atmospheric electrical conductivity and current density on the surface of ground of hilly (high altitude) areas have been found to be increased with height from sea level, while constant value is observed for the electric field in all instants and atmospheric potential on surface of ground of hilly (high altitude) areas decreases with height from sea level (altitude) in Sri Lankan orography (This is not confused with the vertical upward variation at a particular place). Best fit regression lines along with the statistical parameters between the atmospheric electrical parameters and different heights from sea level have been utilized for the different orography of Sri Lanka when clean and clear atmosphere are being existed to verify the assumption of fair weather conditions.

Keywords: Atmospheric conductivity; Electric field; Orography; Cosmic rays.

1. INTRODUCTION

Atmospheric electricity is one of the longest-investigated geophysical topics with a variety of measurement technologies[1]. The atmospheric electricity not only depends upon the mechanism of thundercloud charge generation and separation, lightning and

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atmospheric electrical conductivity, but also upon other environmental factors such as solar activity, air pollution due to industrial emissions, various meteorological parameters and others[2]. Agarwal *et al.*[3] made an attempt to study the effect of cosmic rays, surface radioactivity and particulates present in the atmosphere on the atmospheric electrical parameters, but they took small-scale orographic features (0.6° mesh in latitude and longitude) of the Indian subcontinent. Tinsley[4] studied on the variability of the columnar resistance in global electric circuit but his calculations were limited to stratospheric region. Velinov and Tonev[5] developed a quasi-static model for electric currents from thunderstorms to the ionosphere. It appears that there exists a gap in the data available, in respect of variation of atmospheric electrical parameters with orography over different places of Sri Lanka and proper analyzing of the data. In the present work, first we have collected the geographical data for different places of Sri Lanka from the link (http://www.ncdc.noaa.gov/oa/climate/rcsg/cdrom/ismcs/alphanum.html) and then estimated some atmospheric electrical parameters like conductivity, air earth current density, electric field and atmospheric electric potential over 210 different places of Sri Lanka by taking into account the clean and clear atmosphere.

2. THEORETICAL MODELS

Hays and Roble[6] divided the atmosphere into four coupled regions: lower troposphere, upper troposphere, mesosphere and magnetosphere. The first region up to about 9 km is of much importance due to the earth's orography and varying electrical conductivity which increases exponentially with altitude[7], i.e.

$$\{\sigma(z,\theta) = \sigma_{sl}\, exp[z/2S_1(\theta)]\} \qquad z < z_1 \qquad (1.1)$$

$$\{\sigma(z,\theta) = \sigma_r(\theta) exp[z/2S_2(\theta)]\} \qquad z \geq z_1 \qquad (1.2)$$

where,

z Height from the sea level and θ is the colatitude.

z_1 Height of the boundary separating lower troposphere from the upper troposphere.

σ_{sl} Sea level conductivity.

$S_1(\theta)$ and $S_2(\theta)$ Conductivity scale heights.

$\sigma_r(\theta)$ Reference conductivity[8].

The columnar resistance, $R_{cl}(\theta)$, between the ionosphere and the earth surface is evaluated by

$$R^{cl_1}(\theta) = \int_z^{z_i} \frac{1}{\sigma(z,\theta)} dz \qquad 0 \leq z \leq z_i \qquad (2)$$

where, z_i is the height of the ionosphere (60 km).

The air-earth current density, $J(z,\theta)$ can be estimated as

$$J(z,\theta) = \frac{\Phi_i}{R_{cl}(\theta)} \qquad (3)$$

where, Φ_i is the ionospheric potential (300 kV)

Then, the electric field, $E(z,\theta)$ can be calculated as

$$J(z,\theta) = \sigma(z,\theta).E(z,\theta) \qquad \text{Am}^{-2} \tag{4}$$

The electrostatic potential, $\phi(z,\theta)$ may be expressed by the equation

$$\phi(z,\theta) = \int_{z}^{z_i} E(z,\theta)\, dz \qquad \text{kV} \tag{5}$$

3. RESULTS AND DISCUSSION

The plot of atmospheric electrical conductivity versus ground height from sea level along with the trend line is shown in Figure 1. The trend line for the variation of conductivity with height from sea level was found to be of exponential form which shows the correctness of our data for the orography of Sri Lanka and horizontal effects are being normalized.

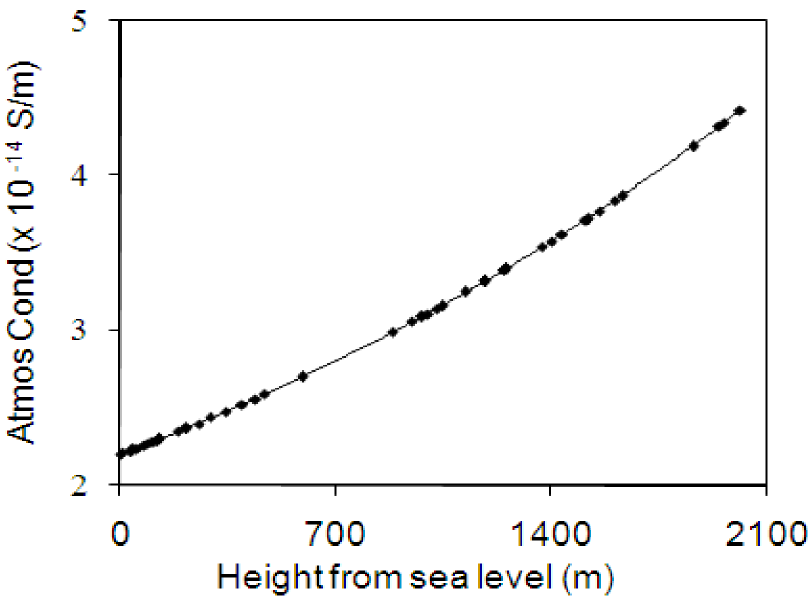

Figure 1: Variation of Atmospheric Conductivity with height from sea level (altitude) for different places of Sri Lanka

In the present work of Sri Lankan orography, height from sea level varies between 3 m and 2013 m whereas the conductivity over different places of Sri Lanka was found to lie between 2.2×10^{-14} Sm^{-1} and 4.42×10^{-14} Sm^{-1}. The atmospheric conductivity for hilly places (altitude >1800 m) of Sri Lanka such as Heramitipana (1861 m), Ambewela (1944 m), Gorandihela (1958 m) and Nuwara Eliya (2013 m) have been found to be 4.19×10^{-14} Sm^{-1}, 4.32×10^{-14} Sm^{-1}, 4.34×10^{-14} Sm^{-1} and 4.42×10^{-14} Sm^{-1}, respectively, whereas for some plain places (attitude < 8 m) such as Jomahandigoda (3 m), it has a uniform value of 2.2×10^{-14} Sm^{-1} reflecting the orographic feature as reported by Makino and Ogawa[9]. Further, the experimental value reported by Saxena and Kumar[10] for ground based atmospheric electrical conductivity at Roorkee (275 m above sea level) of India was 2.65×10^{-14} Sm^{-1} and this closely agrees with our theoretical result of 2.44×10^{-14} Sm^{-1} at

Andagala (295 m above sea level,) of Sri Lanka. Moreover, Guha *et al*.[11] reported the average peak bipolar atmospheric electrical conductivity at the ground level to be around 2.10×10^{-15} Sm^{-1} at Tripura, Northeast India (43 m above sea level) which is in agreement with our theoretical result of 2.21×10^{-15} Sm^{-1} at Lanumodara (32 m above sea level) of Sri Lanka. These experimental findings of atmospheric electrical conductivity clearly validate our theoretical results over Sri Lankan orography.

The variation in conductivity for the place of maximum height as recording level from sea level (Nuwara Eliya, 2013 m) to that for the minimum height as recording level (Jomahandigoda, 3 m) of present Sri Lankan orography is about 53 %, whereas for locations of highest (Erawula Pahalagama, 07º 50´**)** and lowest latitude (Lanumodara, 06º 01´) of Sri Lankan orography, it is about 13 %. These results show that the latitudinal effect is smaller than the orographic effect. This is in conformity with the work of earlier investigators[7].

The calculated values of air-earth current density for mountainous places of Sri Lanka such as Heramitipana (1861 m), Ambewela (1944 m), Gorandihela (1958 m) and Nuwara Eliya (2013 m) have been found to be 4.37×10^{-14} Am^{-2}, 4.49×10^{-14} Am^{-2}, 4.52×10^{-14} Am^{-2} and 4.60×10^{-14} Am^{-2} respectively. The current density over places close to sea level such as Jomahandigoda has been found to be 2.29×10^{-12} Am^{-2}. Guha *et al.*[11] have investigated experimentally the air-earth current density at Tripura, Northeast India (43 m above sea level) to be around 2.10×10^{-12} Am^{-2} which agrees closely with our theoretical result over Padalangala (43 m above sea level) of Sri Lanka.

Figure 2 shows a plot of current density versus height from sea level along with the trend line. The variation in air-earth current density for the place of maximum height from sea level to that for the minimum height of Sri Lankan orography is about 50 % decrement, where as for locations of highest and lowest latitudes, it is about 8 %. These results show that the latitudinal effect is much smaller than the orographic effect.

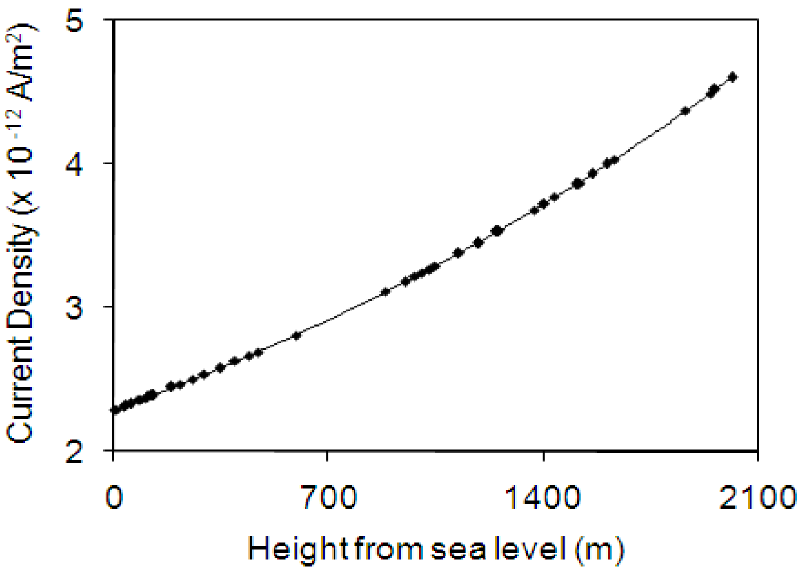

Figure 2: Variation of Air-earth current density with height from sea level (altitude) for different places of Sri Lanka.

The mean value of electric field over 210 different places of Sri Lanka has been found to be 104.08 V/m. Agarwal and Varshneya[7] reported it to be 110 V/m over the Indian subcontinent whereas Guha *et al.*[11] found experimentally the average vertical potential gradient at Tripura, Northeast India (43 m above sea level) to be around 108 V/m. These results are again very close in order with our theoretical results over various places of Sri Lanka. The plot of atmospheric electric field versus height from sea level along with the trend line is shown in Figure 3. The atmospheric electric field slightly decreases with increasing height from sea level. The electric field over various places of Sri Lanka ranges between 103.97 V/m and 104.20 V/m, whereas the average value of it in our calculations has been found to be around 104.08 V/m. The electric field over mountainous regions of Sri Lanka such as Heramitipana and Nuwara Eliya have been found to be 104.06 V/m and 104.08 V/m, respectively. Again, these results show that orography of the earth surface plays an important role in the estimation of electric field.

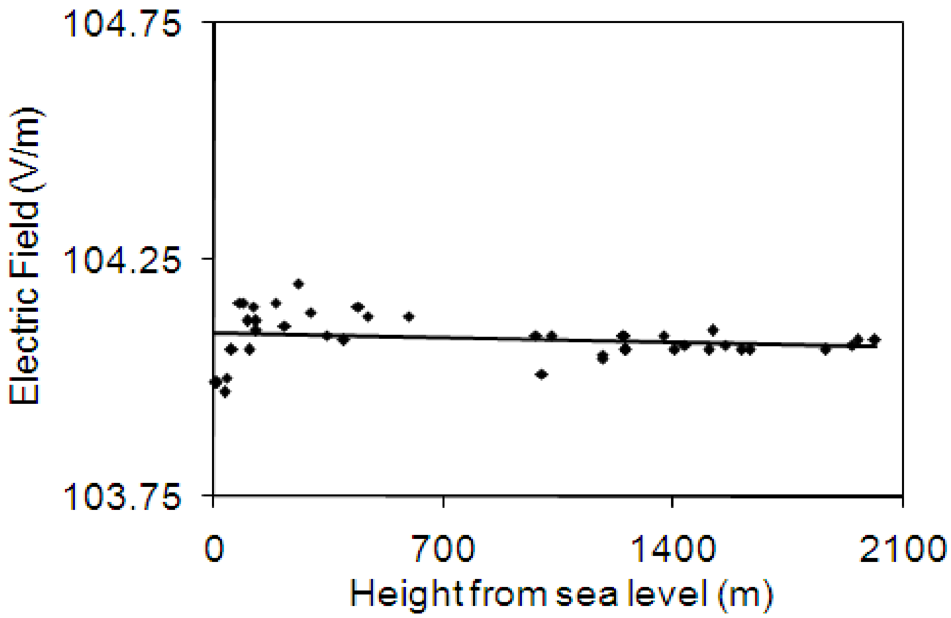

Figure 3: Variation of Electric field with height from sea level (altitude) for different places of Sri Lanka.

The calculation for atmospheric electrical potential has been made for different locations of Sri Lanka at a constant height of 9 km from the place concerned, since 90 % of the atmospheric potential has been found to be lying at about 10 km above sea level[7] (altitude). A plot indicating the variation of atmospheric potential with height from sea level (altitude) over different places of Sri Lanka is shown in Figure 4. The electrical potential decreases with increasing height. The atmospheric potential over different places of Sri Lanka varies between 273.43 kV and 286.73 kV, whereas the average value of it in our calculations has been found to be around 281.79 kV.

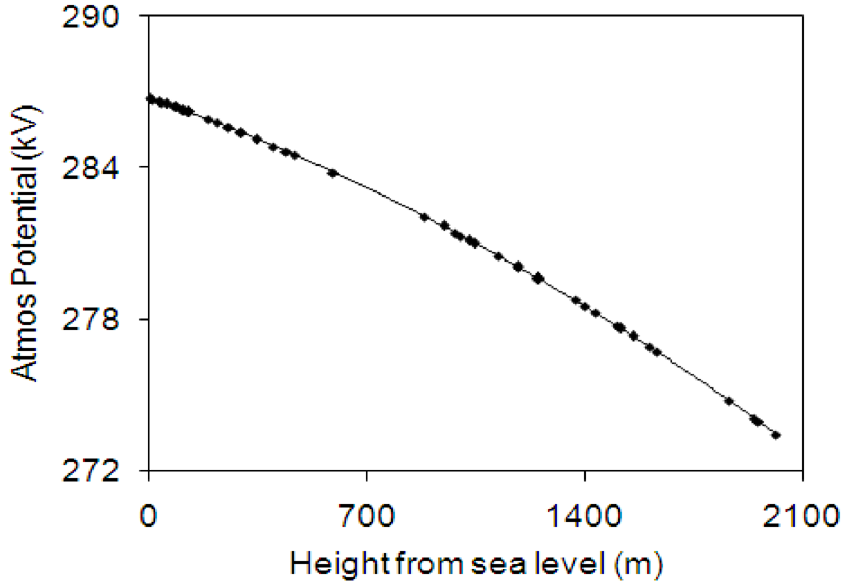

Figure 4: Variation of Atmospheric potential with height from sea level (altitude) for different places of Sri Lanka.

From these results, it is concluded that the latitudinal feature also plays an important role in determining the atmospheric electrical parameters. We have obtained the best fit regression line for different parameters with height from sea level (altitude) by curve fitting (Figures 1 - 4). These best fit regression lines along with statistical parameters such as mean, mode and average deviation values are given in Table 1, whereas the different calculated mathematical parameters such as correlation, kurtosis, pearson and skewness coefficients over the orography of Sri Lanka are given in table 2.

Table 1: Calculated statistical parameters along with best fit lines of different atmospheric electrical parameters for various places of Sri Lanka. Here, z represents the height of the place above sea level (altitude).

Atmospheric Electrical Parameters	**Mean**	**Mode**	**Average Deviation**	**Best fit regression line**
Electrical Conductivity (S/m)	3.30×10^{-14}	3.32×10^{-14}	0.59	$\sigma = (2.20 \exp^{0.001z}) \times 10^{-14}$
Current Density (A/m^2)	3.15×10^{-12}	3.53×10^{-12}	0.61	$J = (2.29 \exp^{0.001z}) \times 10^{-12}$
Electric Field (V/m)	104.08	104.06	0.03	$E = (104.10 - 10^{-5}z)$
Atmospheric Potential(kV)	281.79	279.63	3.55	$\Phi = (286.70 - 0.004z - 10^{-6}z^2)$

Table 2: Calculated mathematical coefficients of different atmospheric electrical parameters for various places of Sri Lanka.

Atmospheric Electrical Parameters	**Correlation**	**Kurtosis**	**Pearson**	**Skewness**
Electrical Conductivity (S/m)	0.99	-1.06	0.99	0.33
Current Density (A/m^2)	0.99	-2.12	0.99	0.34
Electric Field (V/m)	-0.17	0.26	-0.17	0.00098
Atmospheric Potential(kV)	-0.99	-1.06	-0.99	-0.34

Atmospheric conductivity and current density increase with height from sea level over Sri Lankan orography. The electric field is constant and atmospheric potential decreases with altitude. It is one of the important feature that in lower troposphere the global atmospheric electrical parameters are the function of height from sea level along with other parameters like aerosol concentration, ionization due to cosmic rays, radioactivity, solar-terrestrial relationship. From the results, it appears that the atmospheric potential for various places of Sri Lanka is around 282 kV. This is important as all values of potentials are expected to converge to a common value.

In the present work, estimations have been made for global atmospheric electrical parameters viz. atmospheric conductivity, air-earth current density, electric field and atmospheric potential over 210 different orographic important places of Sri Lanka under fair weather conditions. It has been found that while atmospheric conductivity and current density increase with height from sea level, electric field is constant and atmospheric potential decreases. The atmospheric electrical conductivity and air-earth current have been found to be larger over mountain places of Sri Lanka (e.g. Heramitipana, Ambewela, Gorandihela, Nuwara Eliya etc) whereas at places close to the ocean of Sri Lanka (Jomahandigoda, Kottegoda, Lanumodara etc) , these atmospheric electrical parameters have been found to be smaller.

Further, this is in close agreement with the work of Kumar *et al.*[8] where the conductivity at places close to the ocean (altitude 12 m) like Vishakhapatnam of India was found to be 2.2×10^{-14} Sm^{-1} whereas that for hilly places like Kodaikanal (2.343 km) was reported to be 5.29×10^{-14} Sm^{-1}. Kumar *et al.*[8] reported the current density for Kodaikanal and Vishakhapatnam of India were 5.39×10^{-12} Am^{-2} and 2.40×10^{-12} Am^{-2} respectively. The results of US orography were further supported by Kumar *et al*.[8] where they have found average electric field and atmospheric electrical potential over different places of India to be around 109 V/m and 274 kV respectively.

4. CONCLUSIONS

In the present research work, analyses have been made for global atmospheric electrical parameters viz. atmospheric conductivity, air-earth current density, electric field and atmospheric potential over 210 different orographic important places of Sri Lanka under fair weather conditions. It has been found that while atmospheric conductivity and current density increase with height from sea level, electric field is constant and atmospheric potential decreases. The atmospheric electrical conductivity and air-earth current have been found to be larger over mountain places of Sri Lanka (e.g. Heramitipana, Ambewela, Gorandihela, Nuwara Eliya etc) while at places close to ocean of Sri Lanka (Jomahandigoda, Kottegoda, Lanumodara etc), these atmospheric electrical parameters are determined to be smaller. Therefore, it is concluded that orography plays a significant role in fair-weather atmospheric electricity variations.

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