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Effect of Orography on Fair - Weather Atmospheric Electric Field in Kashmir Valley, India.

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ABSTRACT:

Atmospheric electric parameters like electric field change with orography of earth's surface due to changes in ionisation rates, radioactivity and concentration of cloud condensation nuclei changes with altitude of a place. This work presents atmospheric electric field of three different sites in Kashmir valley which have been calculated theoretically and measured experimentally. Fair weather conditions were taken into account for both while selecting data for observational results and calculating the values theoretically. The results obtained of both are in accordance with each other, thus, verifying that orography plays an important role in determining the atmospheric electric field.

KEYWORDS: *Electric field, Fair- weather, Orography.*

INTRODUCTION:

The atmospheric electrical parameters have been studied by a lot of researchers for a long period of time over various locations of globe. These parameters depend on factors such as thunderclouds, meteorological factors, solar activity and pollution. The PG shows a diurnal variation which closely follows the pattern of world thunderstorm activity. This was used to formulate the global electric circuit. Atmospheric electric parameters like potential gradient and air- earth current density can be explained by diurnal variation of thunderstorms whereas parameters like conductivity is influenced by formation and recombination/ attachment rate of ions (Making & Ogawa, 1984).

The lower troposphere region of the atmosphere, upto height of 9 km, is the most important region while considering the effect of orography on atmospheric electric parameters. The electrical conductivity changes with altitude (Agarwal & Varshneya, 1993) due to varying ionisation rates because of the orography of the earth's surface (Srinivas & Prasad, 1993). Ionisation caused mainly due to radioactivity of earth is destroyed due to adhesion to large nuclei. Atmospheric electric parameters like conductivity and current density increase with height from sea level while electric field decreases. This happens because parameters like ionisation due to cosmic rays, radioactivity etc. varies with altitude of a place. Also, the concentration of cloud condensation nuclei increases with altitude of a place, thus mountainous regions have higher cloud condensation nuclei than the plains (Siingh et al., 2007).

Solar flares and coronal mass ejections (CMEs) from sun release lots of highly energetic particles. If they are in right position, these can interact with earth's atmosphere (Dickinson, 1975) via the solar wind and interplanetary magnetic field and be known as solar proton event. These energetic particles interact with earth's lower and middle atmosphere causing ionisation up to about 60 km from earth's surface(Baumgaertner et al., 2013) or by affecting nucleation of water drops to form clouds(Rycroft et al., 2000). The layer of atmosphere from 60km to 300 km is known as ionosphere. This process has very important role in ionisation on earth's surface and thus the GEC. Therefore, it can be expected that the atmospheric electrical parameters will be influenced by solar activity.(Hays & Roble, 1979) using a quasi-static model calculated that changes in conductivity due to solar flares can affect the global electric circuit. The atmospheric electric field increases during solar flares in mountainous regions (Makino & Ogawa, 1985).

Kumar et al., (1998) did a theoretical study of variation of atmospheric electric parameters with orography for 39 cities of India assuming fair weather conditions. They found that conductivity of places with altitude greater than 2100m was higher than places with lower altitude. They found conductivity decreases linearly with decrease in altitude and that the orographic effect is much higher than the latitudinal effect. This was found to be in accordance with result of Agarwal & Varshneya, (1993). The values of electric filed calculated by Kumar et al., (1998) also verified the effect of orography on electric field. The electric field of mountainous regions like Shillong, Shimla, Srinagar etc. were found to be lower (~ 105 Vm^{-1}) whereas places close to sea level had higher values of electric field (~ 110 Vm^{-1}).

Kumar & Singh, (2013) also found a similar increase in conductivity and corresponding decrease in electric field with increasing altitude calculated for 80 orographically different places of India. They took the cosmic ray modulation factor due to forbusch decrease into consideration.

Saxena et al., (2010) collected geographical data for 160 places of US and calculated atmospheric electric parameters like conductivity, air earth current, electric field and potential. The electrical conductivity and current density increases exponentially with altitude. They further reportedthat electric field value remains constant with a value of 112.42 Vm^{-1} while electric potential decreases with increasing height with values ranging between 267.96 kV to 290.34 kV.

It appears that all the workers have attempted to study the effect of orography on atmospheric electricity on a theoretical basis and to the author's knowledge, no study verifies it experimentally. So the authors have conducted a study at 3 different places in Kashmir valley and the results thereof have been presented.

Site description:

The Kashmir valley is surrounded on the south-western side by the Pir Panjal Range and on the north-eastern side by the main Himalayas. A majority of the valley's topography is mountainous, and is divided into 7 zones which are: the plains, foothills, Pir Panjal, Vale of Kashmir, Great Himalayas, Indus river valley and the Karakoram. In order to observe the effect of orography on electric field three sites from Kashmir valley were chosen for study: Srinagar, Tangmarg and Gulmarg.The stations are marked in the topographical map of Kashmir valley (Figure 1).

Srinagarstation is located at an altitude of 1585 metres above mean sea level and has the coordinates (34° 13' N, 74° 83' E). Srinagar city is situated in the centre of Kashmir valley and is the summer capital of union territory of Jammu and Kashmir. The field mill (EFM 100) is installed in the University of Kashmir which lies on the north-eastern bank of world famous Dal lake and has Nigeen lake on the western side. This area is typically of urban nature but does not have any large scale factories and industries nearby. Also, vehicular movement is restricted in the university campus.

The site of Tangmarg station is located at an altitude of about 2080 metres above mean sea level and has the coordinates (34° 06' N, 74° 39' E). This site is rural in nature and is hilly. Most of its area is covered by forests.

The Gulmarg site is located at an high altitude of about 2617.2 meters above mean sea level and has the coordinates (34°05'N and 74°42'E).It lies in the Pir Panjal range and the site is covered by lush green meadows surrounded by green forests of pine and fir. There is no permanent population around the observatory.

All the sites record a temperate climate with temperatures not exceeding about 33° C in summers. Winters are cold in all the stations with sub-zero temperatures recorded during nights. Severe cold conditions are recorded especially in Gulmarg where ground is covered in thick layers of snow for five months of the year. All the observations were carried on fair weather days i.e. days with no precipitation, no local thunderstorms, and clear skies. Sites for observation were chosen carefully with no tall building, trees or electric poles nearby.

RESULTS AND DISCUSSION:

In this work, we have calculated the atmospheric electric field theoretically for the three chosen sites in Kashmir valley and compared our results with experimental values.

The electrical conductivity of a place is given by the equation

$$\boldsymbol{\sigma (z,\theta) = \sigma_{S1} \exp[z/2S_1(\theta)]\ \ Sm^{-1}} \quad (1)$$

where z is the height from sea level

θ is the co-latitude

σ_{S1} is the sea level conductivity = 2.2×10^{-14} Sm^{-1}

$S_1(\theta)$ is the conductivity scale height

The conductivity scale height is given by the equation

$$\boldsymbol{S_1(\theta) = z_1/ \{2 \ln [(\sigma_r(\theta)/\sigma_{S1}) \exp(z_1/2S_2)]\}\ km} \quad (2)$$

where z_1 is the height of boundary layer separating upper and lower troposphere = 9 km

$\sigma_r(\theta)$ is the reference conductivity

S_2 is the scale height of vertical variation of conductivity = 3 km

The reference conductivity is calculated using equation

$$\boldsymbol{\sigma_r(\theta) = \sigma_0\ [1+(\Delta F/2)\ \{1+\cos3(\theta- 30)\}]\ Sm^{-1}} (3)$$

whereσ_0 is the reference conductivity at equator = 1.1×10^{-13}

ΔF is the latitude variation factor due to cosmic rays =0.4

The columnar resistance, $R_c(\theta)$ between the ionosphere and earth's surface is given as the sum of columnar resistance between ground (z_g) and boundary between lower and upper troposphere (z_1) (R_{c1} (θ)); and z_1 and ionosphere (z_i) (R_{c2} (θ)). Hence,

$$\mathbf{R_c(\theta) = R_{c1}(\theta) + R_{c2}(\theta)\ \Omega m^2} \qquad (4)$$

where

$$\mathbf{R_{c1}(\theta)} = \int_{zg}^{z1} \frac{1}{\sigma(z,\theta)} dz\Omega \mathrm{m}^2$$

and

$$\mathbf{R_{c2}(\theta)} = \int_{z1}^{zi} \frac{1}{\sigma(z,\theta)} dz\Omega \mathrm{m}^2$$

The air-earth current is given by

$$\mathbf{J(z,\theta) = \Phi i/Rc(\theta)} \quad (5)$$

where Φi is the ionospheric potential = 300 kV

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

$$\mathbf{J(z,\theta) = E(z,\theta) \times \sigma(z,\theta)\ Am^{-2}} \qquad (6)$$

Using the equations 1 to 6, the values of all the parameters were calculated theoretically and are tabulated in table 1. The parameters calculated have been plotted in figure 2.

As an example the calculations for Srinagar station are shown below:
Reference conductivity has been calculated using equation (3):

$$\sigma_r(\theta) = (1.1\times 10^{-13})\,(1+0.2\,(1+\cos 3(55.87-30)))$$
$$=(1.1\times 10^{-13})\,(1+0.2\,(1.209))$$
$$=1.365\times10^{-13}\ \mathrm{Sm^{-1}}$$

Substitute in equation (2) to calculate the conductivity scale height:

$$S_1(\theta)= 9/2\ \ln[(1.365\times10^{-13}/2.2\times10^{-14}).\ \exp(9/6)]$$
$$=1.352\ \mathrm{km}$$

Substitute the above value in equation (1) to calculate electrical conductivity:

$$\sigma(z,\theta)= (2.2\times10^{-14}).\ \exp(1585/2\times 1352.28)$$
$$= 3.95\times10^{-14}\ \mathrm{Sm^{-1}}$$

The columnar resistance $R_c(\theta)$ is calculated using equation (4):

$$R_c(\theta) = R_{c1}(\theta) + R_{c2}(\theta)\ \Omega m^2$$
$$R_c(\theta) = \int_{1585}^{9} 1/[(2.2\times 10 \wedge -14)\left(\exp\left(\frac{z}{2.704}\right)\right)]dz$$
$$+\int_{9}^{60} 1/[(2.2\times 10 \wedge -14)\left(\exp\left(\frac{z}{2.704}\right)\right)]dz$$
$$=639.86\times10^{14}+44.04\times10^{14}$$
$$= 683.9\times10^{14}\ \Omega m^2$$

Using above value in equation (5), the air- earth current density can be calculated as:

$$J(z,\theta)= 3{,}00{,}000/\ 683.9\times10^{14}$$
$$= 4.386\times10^{-12}\ \mathrm{Am^{-2}}$$

Substituting the value of J (z, θ) and σ (z, θ) in equation (6), we get the value of electric field, E(z, θ) as

$$E(z,\theta) = J(z,\theta)/\sigma(z,\theta)$$
$$= 4.386\times10^{-12}/3.95\times10^{-14}$$
$$= 111.03\ \mathrm{Vm}^{-1}$$

To measure the values of atmospheric electric field at ground surface an electric field mill (EFM 100) was used. In Srinagar station, the field mill was installed on a roof top with height 5.4m from the ground which led to an increase in the electric field values. So, a correction factor was calculated by placing the mill flush with the ground. The values of electric field were then corrected by multiplying with this correction factor. The average electric field was found to be 148.54 Vm^{-1}. In Gulmarg station, the electric field mill was placed at a height of about 4m from the ground surface and a correction factor was calculated in a similar manner to Srinagar station. The average value of electric field observed was 111.21 Vm^{-1}. At Tangmarg station the field mill was placed was placed at ground surface, so no correction factor needed to be calculated and the average value of electric field was 113 Vm^{-1}. These results have been plotted in figure 3.

There seems to be a good correlation between the theoretical and observed values of electric field except for Srinagar station where observed values are higher than theoretical values which can be attributed to relatively higher amount of pollution at the station. Aerosols are capable of modifying the electric field of atmosphere by acting as a platform for recombination of ions leading to ion loss. In addition, pollutants lower the ion mobility, reducing the conductivity, thus increasing potential gradient (Harrison & Carslaw, 2003; Williams, 2003).

CONCLUSION:

The good agreement between theoretically calculated and observed values proves that orography of a place plays a very important role in fair weather atmospheric electric field.

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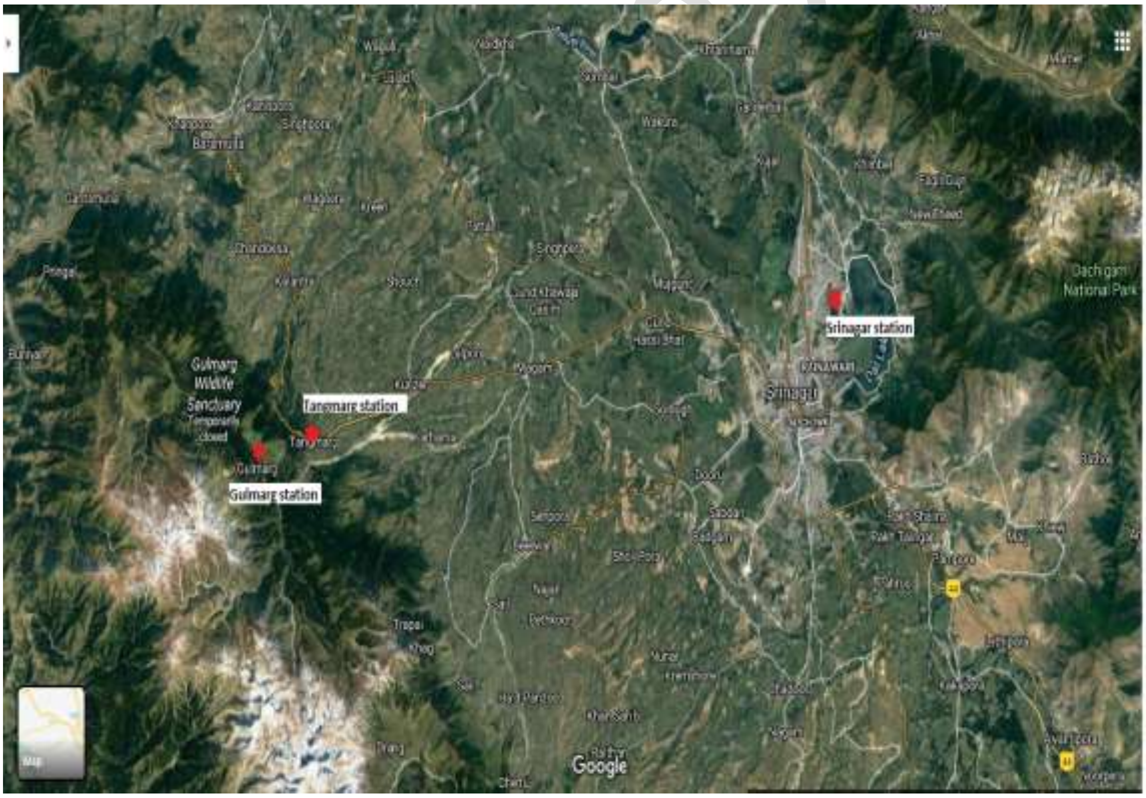
Tables:

Station	Latitude	Longitude	Height from sea level (m)	Conductivity $\times 10^{-14}$ Sm^{-1}	Current density $\times 10^{-12}$ Am^{-2}	Electric field Vm^{-1}
Srinagar	34° 13’ N	74° 83’ E	1585	3.95	4.386	111.03
Tangmarg	34° 06’ N	74° 39’ E	2080	4.80	5.24	109.1
Gulmarg	34° 05’ N	74° 42’ E	2617.2	5.86	6.34	108.1

Table 1: Calculated values of atmospheric electric parameters of the three stations of Kashmir valley considering fair weather conditions.

Figure legends:
Figure 1: Topographical map of Kashmir valley showing the location of three stations.
Figure 2: Calculated atmospheric electric parameters for three stations in Kashmir valley.
Figure 3: Observed electric field values for the three stations in Kashmir valley.



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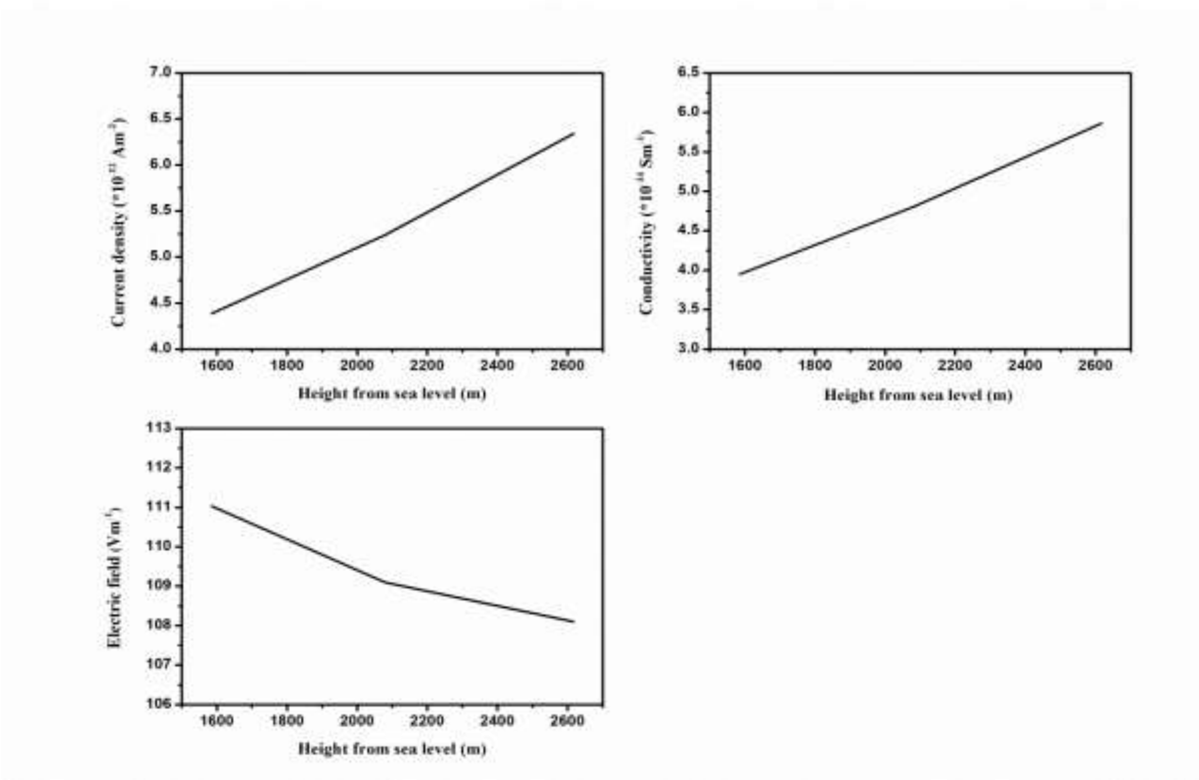
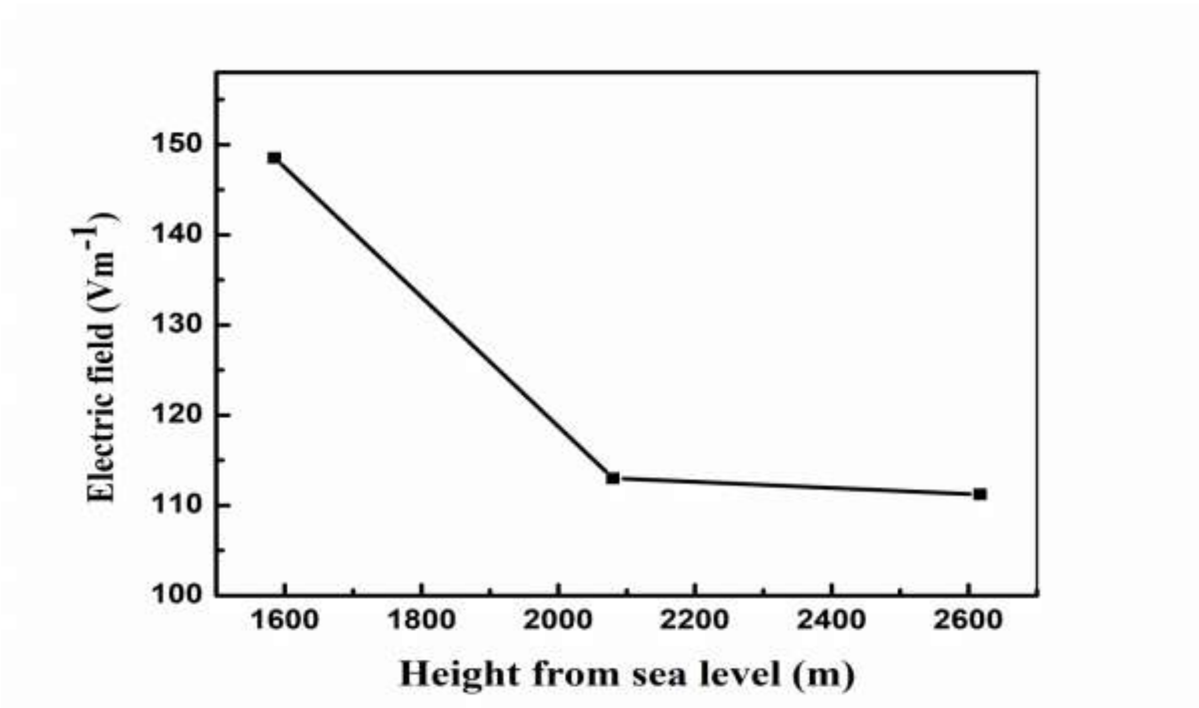


Figure 2: Calculated atmospheric electric parameters for three stations in Kashmir valley.



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