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IMPECT OF SOLAR ACTIVITY ON ATMOSPHERIC ELECTRICAL PARAMETERS OVER SOME DIFFERENT OROGRAPHICALLY PLACES OF INDIA

DEEPTI SAXENA

Department of Physics, Ismail National Mahila PG College, Meerut (U.P.), India

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Some global atmospheric electrical parameters related with environment such as atmospheric conductivity, air-earth current density, atmospheric potential and atmospheric electric field have been calculated for 40 different orographically place of India under the influence of cosmic rays modulation factor due to for bush decrease assuming fair weather conditions. The results have been compared with the earlier work of Kumar *et al* (1998) and shows the correlation between cosmic rays and global atmospheric electrical parameters near the earth's surface which depends upon the magnitudes of galactic cosmic rays (GCR) particles.

INTRODUCTION

The modulation of cosmic rays incident on the earth's upper atmosphere by solar activity results in charging the global electrical properties of the atmosphere, which is in turn believed to affect on weather and climate. In this paper an attempt has been made to summarize the present understanding of earth's atmospheric processes that are affected by cosmic rays.

Some investigators (Markson and Muir, 1980) suggest that the global atmospheric electrical parameters are influence by the solar activity. Since the global electric circuit (GEC) describes the electrical environment of earth's near space, the solar activity is known to change the overall state of ionization (Agarwal and Varshneya, 1993). The cosmic rays are one of the chief indicators of solar activity (Trakhtengerts, 1994). The solar activity influences the intensity of thundercloud electrification by changing the middle atmospheric conductivity above the top of the thundercloud (Markson, 1978). The ionization rate of the atmosphere is the controlling element of the global electric circuit and is significantly affected by solar variability. Therefore, it is reasonable to expect that the atmospheric electrical parameters will be affected by solar activity.

In recent years, considerable attention has been paid to the GEC mode that may provide better insight into the possible electrical coupling mechanism responsible for the observed variations. Hays and Roble, (1979) developed a quasi-static model using spherical harmonic functions, which include the geographical distribution of thundercloud activity, effect of earth's orography and electrical coupling along geomagnetic field lines in the ionosphere and magnetosphere. Their calculations suggest that changes in conductivity due to solar flares are capable of affecting the global electric circuit on the global scale. However, their results did not explain the fact that both the atmospheric electric field and current increase after a solar flare. Tzur and Roble (1985) used a two dimensional model to calculate the atmospheric electrical response resulting from solar proton events and from Forbush decrease in cosmic ray flux following a solar flare. Makino and Ogawa (1984) have developed a numerical model including earth's orography and global distribution of thunderstorm generators. Their results suggest that the decrease in cosmic ray flux has significant influence on the GEC parameters. Their calculations also explain the increase in both atmospheric electric field and air-earth current during solar flare events in high mountain stations. Also, Makino and Ogawa (1985) improved their earlier model by incorporating the latitudinal, longitudinal and height variations of conductivity. Sapkota and Varshneya (1990) estimated the response of the global circuit to the Forbush decrease in cosmic ray flux. But the calculations of Makino and Ogawa (1985) and Sapkota and Varshneya (1990) were performed on the global basis in a grid of 5° both in latitude and longitude. Agarwal and Varshneya (1993) made calculations for GEC parameters by taking the latitudinal variation factor due to cosmic rays as 0.4 for clean and clear atmosphere but they took orography of Indian subcontinent.

Although many correlations of solar activity with global atmospheric electrical parameters at different geographic locations and altitudes are available in literature, but no theoretical details explaining all the observations for small scale feature in response to solar activity are known. Therefore, the purpose of this paper is to determine the response of the global electric circuit in relation with decrease in cosmic ray flux. The global atmospheric electrical parameters viz atmosphere conductivity, air-earth current density, electric filed and atmosphere potential have been estimated by taking the height and latitude variation in cosmic ray flux due to Forbush decrease for 40 different cities of India assuming fair weather conditions. In the present work first we have collected only the geographical data (viz. longitude, latitude and altitude above sea level) for different places from the link (http://www.ncdc.noaa.gov/oa/climate/rcsg/cdrom/ismcs/alphanum.html). However the atmospheric electrical parameters like atmospheric conductivity, air-earth current density etc. have been calculated with the help of theoretical model incorporating the effect of cosmic rays which is clearly discussed in section 2.

GLOBAL ATMOSPHERIC ELECTRICAL PARAMETERS

Makino and Ogawa (1985) suggested that the atmospheric electric global circuit is a current system in which current flows upward from thunderstorm current generator through the ionosphere and down to the earth's surface in the fair weather regions, such that

$$\nabla . J = J_s$$

where, J_s is the point current source at the thundercloud centre and J is the current density in fair weather region.

Hays and Robble (1979) divided the atmosphere into four coupled regions; lower troposphere, upper troposphere, mesosphere and magnetosphere. The first region upto about 9 Km is of much importance due to the earth's orography and varying electrical conductivity which increases exponentially with altitude (Agarwal and Varshneya, 1993), *i.e.*

$$\sigma (z, \theta) = \sigma_{s1} \exp [z/2S_1 (\theta)] \qquad \text{Sm}^{-1}, z < z_1$$

$$\sigma (z, \theta) = \sigma_r \exp [z/2S_2 (\theta)] \qquad \text{Sm}^{-1}, z \geq z_1$$

where, z Height from the sea level and θ is he colatitude. The colatitude is the complete of latitude.

z_1 Height of the boundary separating lower trosposphere from the upper troposphere (= 9 Km)

$\sigma_{sl}(\theta)$ Sea level conductivity $(= 2.2 \times 10^{-14}\ \mathrm{Sm}^{-1})$

$S_1(\theta)$ and $S_2(\theta)$ are the conductivity scale heights. The scale height $S_1(\theta)$ is given by

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

where $\sigma_r(\theta)$ is the reference conductivity and is given by

$$\sigma_r(\theta) = \sigma_0 [1 + (F/2)\ \{1 + \cos 3(\theta - 30°)\}]\ \mathrm{Sm}^{-1} \qquad \text{for } 30° \le \theta \le 150°$$

and $$\sigma_r(\theta) = \sigma_0 [1 + F]\ \mathrm{Sm}^{-1} \qquad \text{for } 30° < \theta \text{ and } \theta > 150°$$

σ_0 is the reference conductivity at equator $(1.1 \times 10^{-13}\ \mathrm{Sm}^{-1})$, and S_2 is the scale height of vertically variation of conductivity (= 3Km).

F is the height and latitudinal variation in galactic cosmic ray modulation factor. F at an altitude (z from sea level) and colatitude (θ) is written as (Sapkota, 1990).

$$F = \begin{cases} F \min \exp(-z/Sco), & z = 30\,\mathrm{km} \\ F(\text{at } z = 30\,\mathrm{Km}), & z > 30\,\mathrm{km} \end{cases}$$

where Sco is the scale height, calculated as

$$Sco = \frac{Z \max}{\ln\left(\dfrac{F \max}{F \min}\right)}$$

where $z_{\max}$ is maximum value of height from sea level (30 km). $F_{\max}$ and $F_{\min}$ are the maximum and minimum values of galactic cosmic ray modulation factor.

$F_{\max}$ and $F_{\min}$ with $30° \le \theta \le 150°$ are given as

$$F_{\max} = 0.05 + \alpha_{\max} \cos^4(\theta)$$

$$F_{\min} = 0.03 + \alpha_{\max}/15 \cos^4(\theta)$$

Agarwal and Varshneya (1993) reported that the galactic cosmic ray ion production rate is constant at latitudes greater than 60°. Therefore, for all values of $\theta \le 30°$, we take $\theta = 30°$ and for $\theta \le 150°$, we take $\theta = 150°$.

$\alpha_{\max}$ is constant which controls the height and latitudinal variation of cosmic ray flux. Based on the measurement of Neher (1971), $\alpha_{\max}$ is found to lie in between 0.9 to 1.3. We have taken it 1.3 for maximum effect of F.

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

$$R_{cl_1}(\theta) = \int_{z_g}^{z_1} \frac{1}{\sigma(z,\theta)}\, dz\ \Omega m^2, \qquad z_g \le z \le z_1$$

$$R_{cl_2}(\theta) = \int_{z_1}^{z_i} \frac{1}{\sigma(z,\theta)}\, dz\ \Omega m^2, \qquad z_1 \le z \le z_i$$

Therefore,

$$R_{cl}(\theta) = [Rcl_1(\theta) + Rcl_2(\theta)]\ \Omega \mathrm{m}^2$$

where z_i is the height of the ionsphere (60 km) and z_g the ground height from sea level.

The air-earth current density can be estimated as

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

where Φ_i is the ionospheric potential (300 KV)

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

$$J(z, \theta) = \sigma(z, \theta).\ E(z,\theta)\ \mathrm{Am}^{-2}$$

The electrostatic potential (z, e) may be expressed by the equation.

$$\phi(z,\theta) = \int_{z_g}^{z} E(z,\theta)\ dzKV$$

This way, the calculations for the atmospheric electrical parameters were made for 40 different orographically important places of India. The results have been compared with work of Kumar *et al*. (1998) where they taken a constant value (0.4) of galactic cosmic ray variation factor for the orography of Indian subcontinent.

Table 1. Calculated GEC Parameters for *F* with $\alpha_{max} = 1.3$

City	Conductivity ($\times 10^{-14}$ Sm^{-1})	Current Density (10^{-12} Am^{-2})	Electrical Field (V/m)	Atmospheric Potential (kV)
Agartala	2.21	2.24	101.43	274.68
Ahemdabad	2.24	2.27	101.38	274.35
Bangalore	3.04	3.04	99.92	265.80
Bhopal	2.64	2.66	100.65	270.02
Bhubaneshware	2.23	2.26	101.39	274.43
Bhuj	2.26	2.29	101.34	274.13
Kolkata	2.20	2.23	101.44	274.76
Chandigarh	2.48	2.50	100.89	271.70
Chennai	2.21	2.24	101.43	274.68
Darjeeling	4.68	4.54	97.04	249.35
Dibrugarh	2.28	2.31	101.30	273.86
Gauhati	2.24	2.27	101.38	274.36
Goa	2.24	2.27	101.37	274.29
Hyderabad	2.66	2.68	100.61	269.80
Imphal	2.90	2.90	100.19	267.35
Jabalpur	2.52	2.55	100.86	271.29
Jaipur	2.52	2.54	100.87	271.32
Jammu	2.43	2.45	100.84	272.14
Jodhpur	2.37	2.40	101.14	272.92
Kanpur	2.30	2.33	101.27	273.72
Kodaikanal	5.06	4.87	96.40	245.75
Lucknow	2.30	2.33	101.27	273.72

Mangalore	2.28	2.31	101.31	273.94
Mountabu	3.36	3.34	99.37	262.58
Mumbai	2.20	2.24	101.44	274.72
Nagpur	2.24	2.46	101.01	272.18
New Delhi	2.38	241	101.11	272.78
Pachmarhi	3.22	3.20	99.62	264.02
Patna	2.24	2.27	101.37	274.31
Pune	2.68	2.69	100.58	269.66
Ranchi	2.77	2.78	100.42	268.71
Roorkee	2.42	2.44	100.95	272.34
Shillong	3.88	3.82	98.44	257.29
Shimla	4.80	4.65	96.75	248.08
Srinagar	3.96	3.88	97.98	256.17
Tiruchiarapalli	2.26	2.29	101.33	274.06
Thiruvanantha-puram	2.20	2.23	101.44	274.75
Vishakhapatnam	2.20	2.23	101.45	274.79

RESULTS AND DISCUSSION

Figure (a) shows the variation of cosmic ray variation factor with height from sea level whereas Figure (b) shows the plot of cosmic ray variation factor with latitude for 40 different orographically important places of India.

The atmospheric conductivity of hilly places (altitude > 2100 m) like Darjeeling, Shimla and Kodiakanal has been found to be 4.68×10^{-14}, 4.80×10^{-14} and 5.06×10^{-14} Sm^{-1} by taking F with $\alpha_{\max} = 1.3$ (Table 1) whereas for $F = 0.4$, the atmospheric conductivity for these places are 4.96×10^{-14}, 5.11×10^{-14} and 5.39×10^{-14} Sm^{-1} (Table 2) respectively. For places very close to sea level (altitude < 12 m) like Vishakhapatnam, Kolkata, Tiruvananthapuram, and Mumbai, the conductivity is found to be 2.2×10^{-14} Sm^{-1} for each place by taking F with $\alpha_{\max} = 1.3$ and $F = 0.4$ Agarwal and Varshneya (1993) reported the value of atmospheric conductivity as 2.2×10^{-14} Sm^{-1} over oceans around Indian subcontinent which is in full agreement with our calculated values for these places. Figure 1 shows a variation between atmospheric conductivity and height from sea level.

The calculated values of the air-earth current density for mountainous regions such as Pachmarhi, Mountabu, Shillong Srinagar, Darjeeling, Shimla and Kodiakanal have current density 3.20×10^{-12} Am^{-2}, 3.34×10^{-12} Am^{-2}, 3.82×10^{-12} Am^{-2}, 3.88×10^{-12} Am^{-2}, 4.54×10^{-12} Am^{-2}, 4.65×10^{-12} Am^{-2} and 4.87×10^{-12} Am^{-2} by taking F with $\alpha_{\max} = 1.3$ (Table 1) whereas the current density for these places are 3.58×10^{-12} Am^{-2}, 4.33×10^{-12} Am^{-2}, 4.42×10^{-12} Am^{-2}, 5.22×10^{-12} Am^{-2}, 5.35×10^{-12} Am^{-2}, and 5.62×10^{-12} Am^{-2} respectively for $F = 0.4$ (Table 2). Thus, the values of air-earth current density have been found to decrease for these mountainous places in comparison to the results of Kumar *et al.* (1998). But the values of each place increase at low and decrease at high latitudes which is an agreement with the work of Agarwal *et al.* (1993). Figure 2 shows a graph between air-earth current density and height from sea level. The places closes to ocean like Kolkata and Vishakhapatnam have much less effect of cosmic ray flux which is quite obvious since they cosmic rays of the solar origin are known to cause the ionization at altitudes from 15 to 20 km onwards (Herman and Goldberg, 1978).

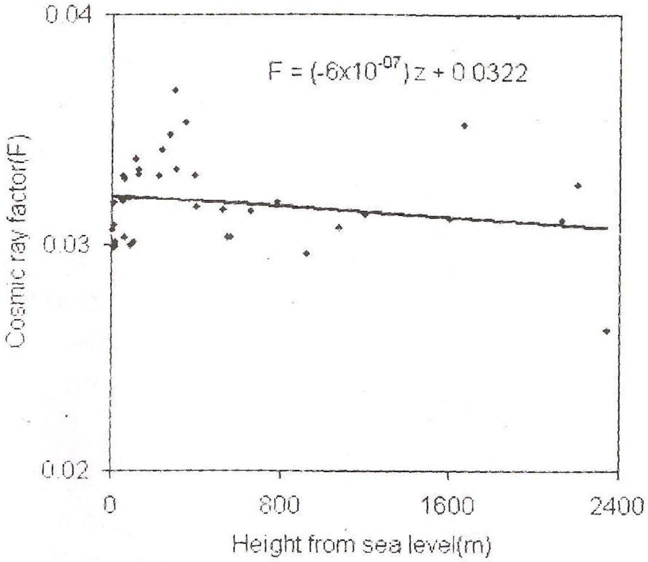

Fig. a. Variation of Cosmic Ray Factor (*F*) with Height from Sea Level

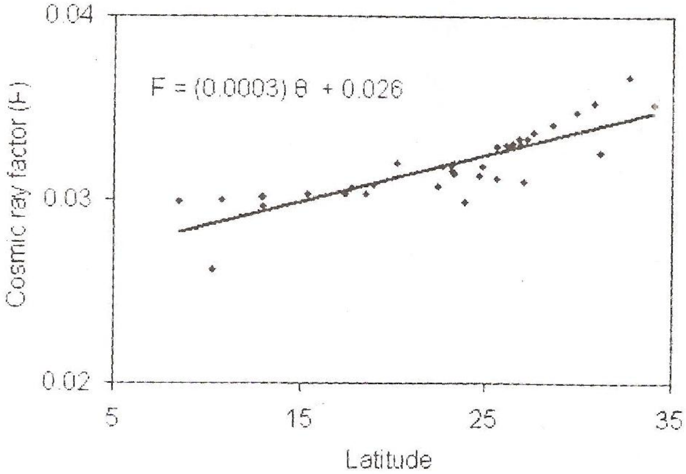

Fig. b. Variation of Cosmic Ray Factor with Latitude

It is estimated from calculations that the electric field over mountainous regions such as Pachmarhi, Mountabu, Shillong, Srinagar, Darjeeling, Shimla and Kodiakanal having altitudes 1075, 1195, 1600, 1666, 2128, 2202 and 2343 meters is 99.62, 99.37, 98.44, 97.98, 97.04, 96.75, and 96.40 V/m respectively by taking *F* with $\alpha_{\max} = 1.3$ (Table 1) whereas for $F = 0.4$ (Table 2), the values of electric field for the above places has been found to be 108.11, 107.82, 106.72, 106.42, 105.05, 104.79 and 104.29 V/s respectively. These results show that the values decrease in each case for all the hilly cities of India. But for an increase in cosmic ray flux, these values somewhat increase which is due to the increase in cosmic ray flux. The places very close to sea level have the average value of around 101.44 V/m. The mean value of electric filed for these 80 different places is found to be 100.51 V/m whereas for $F = 0.4$, this mean value of electric field is found to be 109.17 V/m. These results show that the average value of electric field is in agreement with previous workers (Harrison, 2005). Figure 3 shows a variation of electric field with height from sea level. This graph clearly compares our results with Kumar *et al*. (1998).

Table 2. Calculated GEC Parameters for $F = 0.4$

City	Conductivity ($\times 10^{-14}$ Sm^{-1})	Current Density (10^{-12} Am^{-2})	Electrical Field (V/m)	Atmospheric Potential (kV)
Agartala	2.21	2.43	110.02	278.67
Ahemdabad	2.24	2.46	109.89	278.33
Bangalore	3.11	3.31	106.64	269.52
Bhopal	2.68	2.92	109.04	274.31
Bhubaneshware	2.23	2.45	109.59	278.27
Bhuj	2.26	2.49	109.86	278.14
Kolkata	2.20	2.42	109.93	278.70
Chandigarh	2.51	2.75	109.68	276.04
Chennai	2.21	2.39	108.42	277.97
Darjeeling	4.96	5.21	104.99	254.59
Dibrugarh	2.29	2.52	110.07	278.01
Gauhati	2.24	2.47	110.11	278.44
Goa	2.25	2.45	108.81	277.81
Hyderabad	2.70	2.92	108.27	273.75
Imphal	2.96	3.22	108.61	271.85
Jabalpur	2.55	2.79	109.29	275.49
Jaipur	2.55	2.79	109.53	275.63
Jammu	2.46	2.69	109.74	276.50
Jodhpur	2.39	2.62	109.83	277.11
Kanpur	2.30	2.54	109.99	277.86
Kodaikanal	5.29	5.39	101.94	249.55
Lucknow	2.31	2.54	110.01	277.86
Mangalore	2.28	2.47	108.25	277.27
Mountabu	3.47	3.73	107.62	267.31
Mumbai	2.20	2.41	109.47	278.47
Nagpur	2.46	2.70	109.72	276.44
New Delhi	2.40	2.64	109.88	277.01
Pachmarhi	3.31	3.57	107.74	268.60
Patna	2.25	2.47	110.07	278.38
Pune	2.72	2.94	108.41	273.70
Ranchi	2.82	3.06	108.78	273.08
Roorkee	2.44	2.68	109.81	276.66
Shillong	4.05	4.32	106.59	262.77

Shimla	5.11	5.35	104.79	253.43
Srinagar	4.16	4.42	106.42	261.39
Tiruchiarapalli	2.27	2.45	107.80	277.17
Thiruvanantha-puram	2.20	2.36	107.39	277.57
Vishakhapatnam	2.20	2.40	109.31	278.45

Calculations show that the average value of atmospheric potential for these 40 different places has been estimated to be 269.62 whereas from the investigations of Kumar et al. (1998), it is clear that this average value of potential for F = 0.4 is 273.79 kv. Figure 4 compares our results of potential with height from sea level.

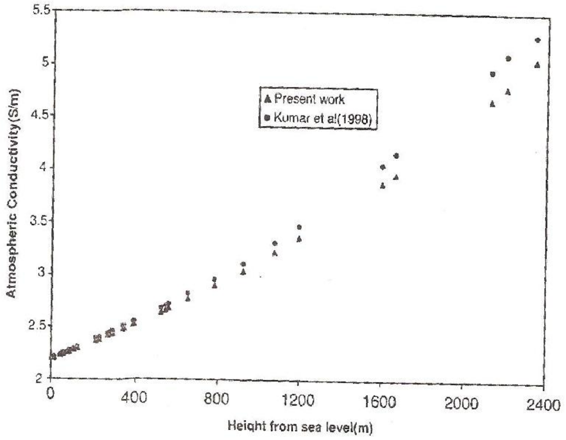

Fig. 1. Atmospheric Conductivity Vs Height from Sea Level

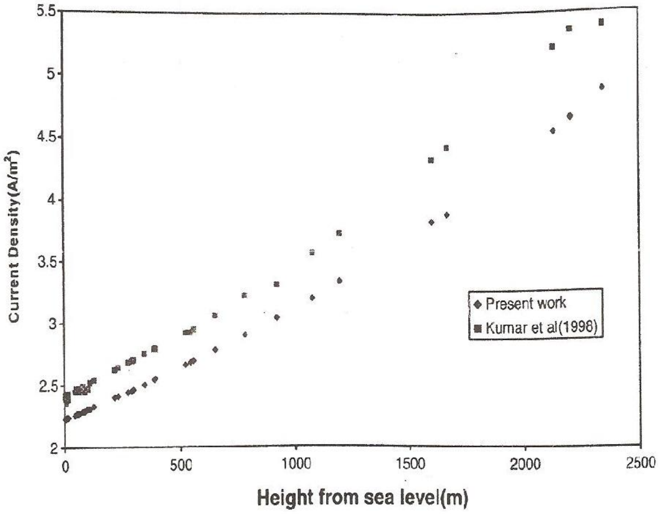

Fig. 2. Current density Vs Height from Sea Level

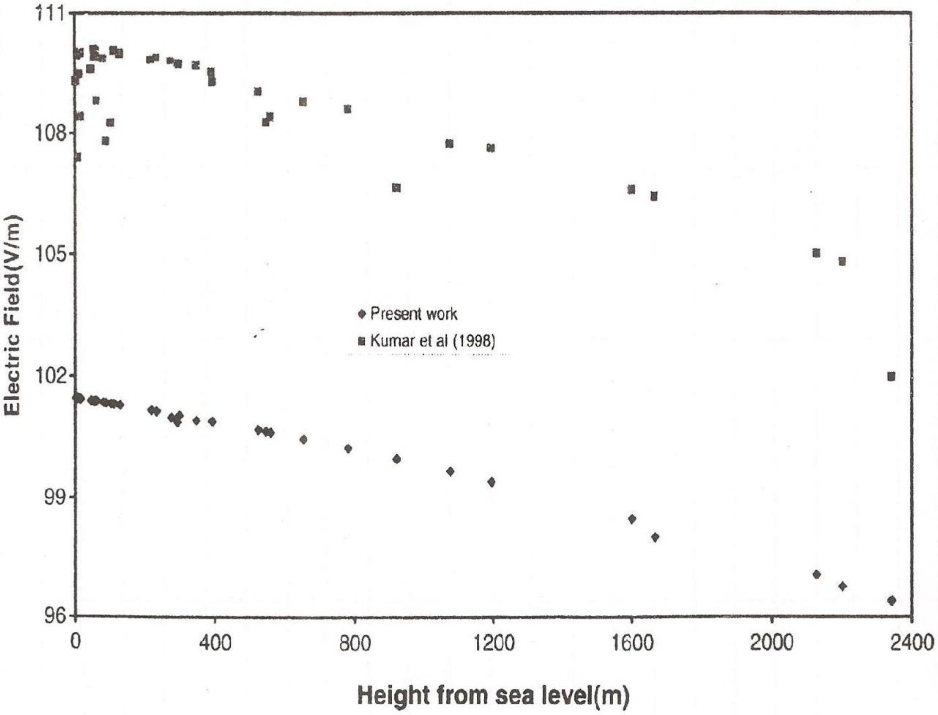

Fig. 3. Atmospheric Electric Vs Height Sea Level

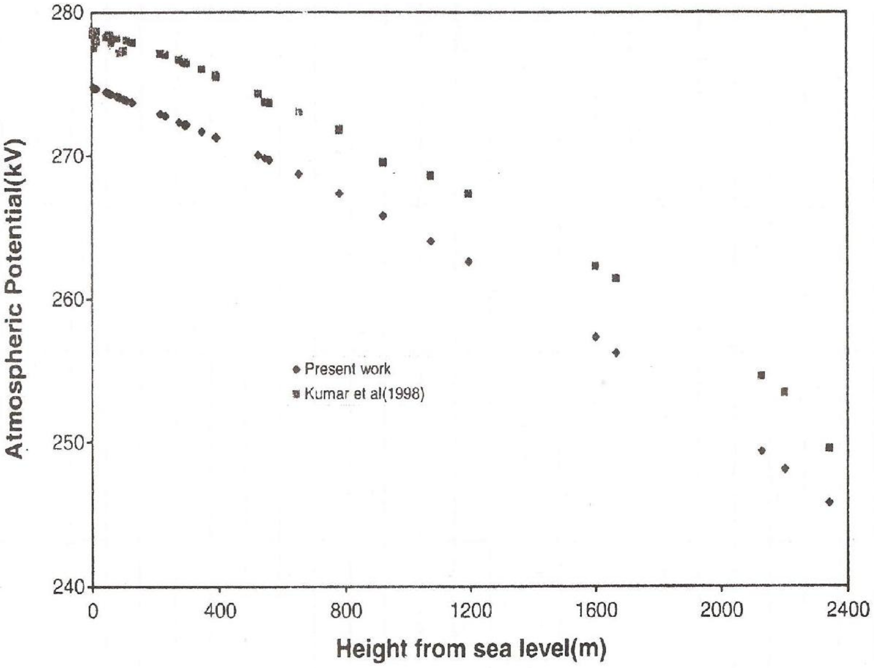

Fig. 4. Atmospheric Potential Vs Height from Sea Level

CONCLUSION

The results of present studies show that the variations in cosmic ray flux affect prominently the earth's environment. The calculated global electric circuit parameters have been found to vary in agreement with the clear response of solar activity. Whereas the solar cosmic ray particles are not able to penetrate the lower atmosphere, the galactic cosmic ray particles create ionization up to ground surface at all altitudes. However, there is a less effect of cosmic rays to places very close to sea level. Kumar *et al*. (1998) found that the orography of the earth surface plays an important role in the determination of global atmospheric electrical parameters. Therefore, it is concluded from the above study that the correlation between cosmic rays and atmospheric electrical parameters near the earth surface depends upon the relative magnitudes of galactic cosmic ray particles.

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