The Effective role of Ions in Clouds and Precipitation Particles to the Electrical Conductivity and Electrification of clouds

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Abstract

For the calculation of the electrical conductivity of electrified clouds, it is assumed that the cloud has a primary positive dipole charge distribution and that the rates of production of ions from cosmic ray ionization, as well as the rates of ion loss from the distinct processes of ion recombination, diffusion, and conduction, control the small ion concentrations. The findings demonstrate that when electric fields are present, the cloud is almost completely incapable of conducting via the tiny ion conduction mechanism. The mechanisms for charge transfer in cloud boundary areas and cloud updraft are investigated, and an estimation of the thickness of the sheathing layer charge distribution in quasi-static cloud boundaries is made. It has been determined that charged cloud and precipitation particles in thunderstorms induce electrical conductivity. This conductivity is discovered to be up to two orders of magnitude more than that of clean air at the same altitude. This conductivity may exhibit significant changes in thunderstorms in both space and time because it rises with the intensity of the precipitation, the liquid water content, the electric field, and the electrical charges on the particles. Despite this high conductivity, it is contended that the related relaxation time may not always be brief, particularly for small-scale space charge regions and individual charged particles. The inconsistencies between the data and past studies may be resolved, according to discussion on the basis of the present results.

Keywords*: Conductivity, Precipitation, Ionization, Charge, Concentration.*

Introduction:

The discussion of behavior of conductivity and small ionic concentration under some meteorological conditions. Comparative planetary science is based on the premise that knowledge of environment of earth may be applied to understanding other environments of planetary, and that knowledge of the terrestrial environment can be expanded through the use of observations from other worlds. A contemporary comparison research of solar system atmospheric electricity is motivated by a number of factors. Firstly, there is data that suggests electrification may be a real-world impact affecting the planet's temperature (Harrison and

Carslaw, [2]) and (Moses et al., [3]), it looks plausible that electrical influences on aerosol particle modifications could cause charged particles atmosphere to affect a radiative balance of planet. Lightning, which is brought on by non-convective and convective electrification are examples of atmospheric electrification. The creation of electrically charged particles, which can come from cosmic rays, radioisotope decay, or UV radiation, is necessary for non-convective electrification. Every planet's atmosphere should include charged particles from ionization due to the universal presence of cosmic rays, which results in a very minor electrical conductivity. The atmospheric charge exchange is complicated by interactions between aerosol particles and the ions and electrons created by cosmic ray ionization.

Measurement of atmospheric ions is employed to study atmospheric electricity and particulate matter pollution. Commonly studied ion parameters are (1) air conductivity versus total ion count concentration, and (2) ion mobility spectra that change with atmospheric composition. A newer development is the computer-controlled attraction capacitor, which extracts ions from (a) the flow of charged particles at the detection electrode and (b) the charge rate of exchange with the electrode at a known initial potential that relaxes to a lower potential. because the voltage drops, only ions with increased mobility are collected by the central electrode, contributing to an extra drop in voltage. this enables us to extend the classical theory to calculate the ion mobility spectrum by reversing the voltage decay time series. In room air, ion mobility spectra determined using both the new drop reversal and the established voltage switching technique were compared and shown to have similar shapes. The air conductivities calculated by integration were 5.3 ± 2.5 f Sm-1 and a couple of .7 ± 1.1 f Sm^{-1}, respectively, and therefore the conductance determined by direct measurement at constant voltage was 3 f Sm-1. Applications of the new Relaxation Potential Inversion Method (RPIM) include retrieval of air ion mobility spectra from historical data and computation of ion mobility spectra in planetary atmospheres.

CTR Wilson proposed that the electrification of the earth's atmosphere is maintained by the existence of an earth-atmospheric circuit (Wilson,) [4] caused by weather disturbances and ionization in the less conductive atmosphere between the surface and the ionosphere arise from the flow of electric current generated. The minimum parameters required for the global atmospheric circuit appear to be the presence of a surface-enclosed atmosphere with a conductive ionosphere and charge-generating mechanisms [19].

The electrical conductivities due to charged clouds and precipitation particles in thunderclouds are calculated. It has been found that the conductivity can be one or two orders of magnitude higher than that of clear air at the same altitude. Conductivity increases with precipitation intensity, liquid water content, electric field, and particle charge, so thunderstorms can exhibit large spatial and temporal variations. However, it is argued that despite this high conductivity, the corresponding relaxation times do not necessarily need to be small. Based on available results, possible compensation for deviations in previous studies and measurements was discussed. There are differing opinions on the importance of electrical conductivity during a thunderstorm. Since small ions produced by cosmic rays should quickly become trapped in cloud droplets, it suggests that the conductivity of cloudy air should be much lower than that of clear air. Measurements from [5], [6], [7], and many others have suggested that the conductivity of cloudy air is similar to that of clear air. The air conductance in thunderstorms, however, can be up to 18 times higher than the air conductance in clear weather at the same altitude, according to [8], who draws this conclusion from a study of electric field recovery curves. [9] measurements in thunderstorms, which support a conductivity of 10–100 times higher than in clear air.

The atmospherical electrical parameters like electrical physical phenomenon, field of force and air-earth current area unit greatly tormented by the geology of earth surface, because the particle concentration because of these sources varies latitudinally and conjointly exponentially with altitude, it causes a similar variation in atmospherically physical phenomenon. The physical phenomenon over high mountains is large; so, a lot of air earth current flows over them than that over ocean. because the variation of physical phenomenon affects some international electrical device (GEC) parameters like air-earth current, atmospherically field of force, etc. it's necessary to check quantitatively the response of those parameters to atmospherical physical phenomenon and thereby their variation with latitude, altitude and geology of the world surface. Many investigators have theoretical calculations of GEC parameters, considering orographic options of earth surface ad reported that geology plays a vital role in GEC. However, a plausible theory of GEC should contemplate a little scale geology with vertical and angular distance variation of electrical physical phenomenon.

The present flow within the international electrical device links area weather and changes within the higher atmosphere levels all the way down to tropospheric cloud levels, wherever it seems to influence precipitation from bound styles of clouds, that successively might influence atmospherically dynamics. The present flow is additionally tormented by internal atmospherical processes. Thus, there is an expectation that changes in clouds globally might even be joined to changes in tropical thunderstorms that act as electrical generators for the circuit.

Table 1-Some Characteristic Features of Atmospheric Particle

S.No.	Type	Range of sizes Diameter in Meter	Concentration No./m^3	Approximate Terminal Velocity (m/s)
1	Gas Molecule	$(2.8\text{-}6.5)x10^{-10}$	Almost $25x10^{24}$	--
2	Small Ions	$(1.5\text{-}10)x10^{-9}$	$(1\text{-}7)x10^{8}$	--
3	Large Ions	$(1\text{-}20)x10^{-8}$	$(2\text{-}20)x10^{9}$	
4	Small Aitkin Condensation Nuclei	$(1\text{-}40)x10^{-8}$	$10^{7}\text{-}10^{11}$	$10^{-7}\text{-}10^{-5}$
5	Large Nuclei	$(4\text{-}20)x10^{-7}$	$10^{6}\text{-}10^{9}$	$10^{-5}\text{-}10^{-4}$
6	Giant Nuclei	$(20\text{-}1000)x10^{-7}$	$10^{2}\text{-}10^{7}$	$7x10^{-4}\text{-}7x10^{-3}$
7	Dry Haze	$(1\text{-}100)x10^{-7}$	$10^{9}\text{-}10^{11}$	
8	Fog and cloud droplets	$(1\text{-}200)x10^{-6}$	$25x10^{6}\text{-}6x10^{8}$	$10^{-4}\text{-}10^{-2}$
9	Drizzle	$(2\text{-}40)x10^{-5}$	$(1\text{-}10)x10^{11}$	$(1\text{-}170)x10^{-2}$
10	Rain drops	$(4\text{-}40)x10^{-4}$	$10^{6}\text{-}10^{9}$	$(17\text{-}90)x10^{-1}$

A brief review is going to be given of the consequences on the world circuit of energetic particle precipitation and changes in polar cap ionospheric potential. The energetic particles area unit galactic cosmic rays (at all times) and MeV electrons and star protons (occasionally, once the stratospheric column resistance is increased by volcanic aerosols or stratospheric clouds).
The current density into clouds generates house charge in conduction gradients, like at the higher and lower boundaries of the clouds, and provides the charge for electro scavenging processes, moreover as for ion-mediated-nucleation each processes seem capable of poignant the concentrations of CCN. Electro scavenging enhances contact ice nucleation in cloud topnotch that area unit super-cooled with broad drop size distributions, e.g., marine stratocumulus in winter. Estimates offer bigger contact nucleation rates than deposition nucleation rates in slightly super-cooled cloud topnotch.
Increases in ice nucleation and reduces in CCN concentration enhance the processes resulting in precipitation and reduction in cloudiness increased precipitation in sure circumstances will cause intensification of winter cyclones, with potential consequences for obstruction things within the general circulation.

Theoretical Consideration:

Destruction of Small Ions in the Atmosphere:

Particles in the atmosphere may be formed through the coagulation of two or more particles. But this process does not produce any new particles. New particles are produced in the atmosphere through a number of mechanisms. The wind stresses and other natural or artificial mechanical stresses can detach the particles from solids through abrasion; fragments can be detached from solids through abrasion, cracking, weathering, etc. and from oceans through breaking of waves, bursting of bubbles, etc. The super saturated vapor can produce solid and liquid elements directly from the water phase by nucleation. In general, the concentration of large nuclei over oceans is one order less than that of over land. About half of small Aitkin concentration nuclei carry a net electrical charge. The small ions will have destroyed by the attachment process to the dissimilarly charged ions and uncharged large nuclei.
A small ion will transform into a large ion when it bonds to an uncharged massive nucleus. The significance of tiny ions comes from the fact that they are primarily responsible for determining electrical conductivity. However, both tiny and big ions work to define the space charge. The radiolysis of air molecules results in the continuous production of small ions in the environment. The three main sources of high-energy particles—radon isotopes, cosmic rays, and terrestrial gamma radiation—all result in the formation of ions in the air. Vertical variations exist in the partitioning between the sources. Ionization from turbulent transport of radon and other radioactive isotopes near the surface across land is significant, as is gamma radiation from isotopes below the surface. Cosmic ray ionisation is constantly (9). The ion mobility spectrum n (μ) describes the distribution of ion number concentration with mobility, where μ is inversely proportional to cluster size and molecular weight. Molecular ions with $0.5 < \mu < 3$ $cm^2V^{-1}s^{-1}$ are conventionally defined as "small ions", as their size is limited by thermodynamic constraints on their lifetime, which generally inhibit ion growth to $\mu \sim 0.5$ $cm^2 V^{-1}s^{-1}$ [2]. The slight electrical conductivity of atmospheric air results from the natural ionization, generated

by cosmic rays and background radioisotopes. For bipolar ion number concentrations n^+ and n^- the total air conductivity σ [1] is given by

$$\sigma = \sigma^+ + \sigma^- = e\,(\mu^+ n^+ + \mu^- n^-)$$

Where μ+ and μ- are the average ionic mobilities and σ+ and σ - are the associated polar conductivities. Air conductivity is strongly affected by aerosol contamination. In aerosol-contaminated air, the build-up of ionic aerosols significantly reduces conductivity [11].

Ionic Equilibrium in the Atmosphere:

The rate of production ions Q is a crucial component of any type theory of induced nucleation because it controls the number of ions that are available for nucleation. [12] contrasted two approaches to estimating Q: 1) Direct measurements of the ionisation sources (Radon, galactic cosmic rays, and ground-based gamma radiation); and 2) Measurements of the 25 distributions of tiny ions and particles followed by the solution of Equation (1) for Q under the assumption of steady state.

$$\frac{dn_\pm}{dt} = Q - \alpha n_\pm^2 - n_\pm \int \sum_{q=-\infty}^{\infty} \beta_\pm\big(d_p.q\big) N\big(d_p.q\big) dq_p \ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

The second part of (1) is the loss of ions by recombination and the third term corresponds to the attachment of small ions to aerosols. n ± is the concentration of either negative or positive ions (assumed to be equal), _ is the ion-ion recombination coefficient, dp is the aerosol diameter, q the charge of the aerosol particle, β± (dp, q), the ion-aerosol attachment coefficient and N (dp, q) the aerosol concentration. Since the recombination and attachment coefficients are known, and the concentrations of ions and aerosols measured, it is possible to estimate Q[19]. The destruction of small ions in the atmosphere is determined primarily by the following factors Radius of large nuclei.

Number of opposite elementary charge on the large nuclei.

Assuming small ions are monodispersing (i.e. all particles having same radius), we can write the time variation of small ions as given below.

$$\frac{dn_1}{dt} = q - \alpha n_1 n_2 - n_1 \int \sum_{P=1}^{\infty} \eta_{12}^P(r) N_2^P(r).dr - n_1 \int N_0(r) \eta_{10}(r) dr ....(2)$$

$$\frac{dn_2}{dt} = q - \alpha n_1 n_2 - n_2 \int \sum_{P=1}^{\infty} \eta_{21}^P(r) N_1^P(r).dr - n_2 \int N_0(r) \eta_{20}(r) dr ....(3)$$

Where,

n_1= Concentration of small positive ions

n_2= Concentration of small negative ions

N_O=Concentration of uncharged nuclei

N_1= Concentration of large positive ions.

N_2 = Concentration of large negative ions.

q = Ionization rate.

P = Number of elementary charges.

α= Coefficient of recombination between n_1 and n_2

η_{12}=coefficient of recombination between n_1 and n_2

η_{21}= coefficient of recombination between n_2 and N_1

η_{10}= coefficient of recombination between n_1 and N_0
η_{20}= coefficient of recombination between n_2 and N_0

Since no sufficient data exists on the aerosol size and corresponding concentration, it is difficult to evaluate the integrals in the above equations. The contribution towards the destruction of small ions by its attachment to the large ions of same sign is ignored.

The distribution function for multiple charges derived from Boltzmann distribution law is still used [13], [14], and [15]. The results of these derivations are uncharged. Therefore, neglecting contribution of multiple charges on larger particles and assuming a constant size distribution we can write an approximate equation for the time variation of ionic concentration.

$$\frac{dn_1}{dt} = q - \alpha n_1 n_2 - \eta_{12} n_1 N_2 - \eta_{10} n_1 N_0 \ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

$$\frac{dn_2}{dt} = q - \alpha n_1 n_2 - \eta_{21} n_2 N_1 - \eta_{20} n_2 N_0 \ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

$$\frac{dN_1}{dt} = \eta_{10} n_1 N_0 - \eta_{21} n_2 N_1 - \nu_{12} N_1 N_2 \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

$$\frac{dN_2}{dt} = \eta_{20} n_2 N_0 - \eta_{12} n_1 N_2 - \nu_{12} N_1 N_2 \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$\frac{dN_0}{dt} = \eta_{12} n_1 N_2 - \eta_{21} n_2 N_1 - 2\nu_{12} N_1 N_2 - \eta_{10} n_1 N_0 - \eta_{20} n_2 N_0 \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where,

ν_{12} = coefficient of recombination between N_1 and N_2.

When there is equilibrium between and destruction of small ions, we get from equations (3.3) and (3.4),

$$q - \alpha n_1 n_2 = \eta_{12} n_1 N_2 + \eta_{10} n_1 N_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(9)$$

$$q - \alpha n_1 n_2 = \eta_{21} n_2 N_1 + \eta_{20} n_2 N_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(10)$$

From these two equations we get

$$\eta_{10} n_1 N_0 - \eta_{21} n_2 N_1 = \eta_{20} n_2 N_0 - \eta_{12} n_1 N_2 \ldots\ldots\ldots\ldots\ldots\ldots....(11)$$

In the same way, we get from equations (3.5) and (3.6), the same result as in equation (3.11) if

$$\frac{dN_1}{dt} = \frac{dN_2}{dt} = 0$$

By substituting

$$\nu_{12} N_1 N_2 = \eta_{10} n_1 N_0 - \eta_{21} n_2 N_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(12)$$

And

$$\nu_{12} N_1 N_2 = \eta_{20} n_2 N_0 - \eta_{12} n_1 N_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.......(13)$$

In equation (3.8) we obtain

$$\frac{dN_0}{dt} = 0$$

Thus we can conclude that large ion and uncharged nuclei concentration will reach the equilibrium condition when small ion concentration does.

If $n_1=n_2=n$ and $N_1=N_2=N$ we get from equation (11),

$$\frac{\eta_{21}-\eta_{12}}{\eta_{10}-\eta_{20}}=\frac{N_0}{N}\qquad(14)$$

If $0<\nu_{12}N_1N_2=\nu_{12}N^2<<1$, we get equation (12) and (13)

$$\frac{N_0}{N}=\frac{\eta_{21}}{\eta_{10}}\qquad(3.15)$$

$$\frac{N_0}{N}=\frac{\eta_{12}}{\eta_{10}}\qquad(16)$$

From equations (3.14), (3.15) and (3.16), we get

$$\frac{\eta_{21}-\eta_{12}}{\eta_{10}-\eta_{20}}=\frac{\eta_{21}}{\eta_{10}}=\frac{\eta_{12}}{\eta_{20}}=\frac{N_0}{N}\qquad(17)$$

From this relation it is clear that our assumption $0<\nu_{12}N^2<<1$ is right**.** [20] Suggested $\nu_{12}\approx 10^{-15}m^3\sec^{-1}$.

Let $A=N_1+N_2+N_0$

Or

$$A=N(2+g)\qquad(18)$$

Where,

$N_0=gN$ And $N_1=N_2=N$.

By using Boltzmann distribution, we can calculate the value of g (ratio of uncharged to charged nuclei) for different sizes of particles. Boltzmann law relates to the distribution of particles with different energy states in the system under equilibrium. If the system does not constitute equilibrium the application of Boltzmann distribution can be criticized. Nevertheless, it provides a simple description of the system. The electrostatic energy (E_e) of a spherical conductor carrying a charge p e (where p is the number of elementary charges) in M.K.S. units is given by

$$E_e=\frac{p^2e^2}{4\pi\varepsilon_0 2r}$$

Where ε_0 is the permittivity of the space (=8.85418x10^{-12} F.m^{-1}). Assuming that the charge on the particle will not distort the none electrostatic energy (E_0) of the particle, the total energy of the particle (E) is given as

$$E=E_0+\frac{p^2e^2}{4\pi\varepsilon_0 2r}\qquad(19)$$

From the Boltzmann distribution the number of particles (N) with p elementary charges will be proportional to

$$N=\exp(-E_0/kT).\exp\left(-\frac{p^2e^2}{4\pi\varepsilon_0 2rkT}\right)$$

Where k (=1.38x10^{-23} J.k^{-1}) is the Boltzzmann constant. The factor E_0 being common to all values of p we can incorporate it in to partition factor Φ (or normalization constant).

Thus the number of particles $N^{(p)}$ per unit volume with p elementary charges is given by

$$N^{(p)} = \phi \exp\left(-\frac{p^2 e^2}{4\pi\varepsilon_0 2rkT}\right)..(20)$$

Thus the number of particles N_0 with no of charges is given as

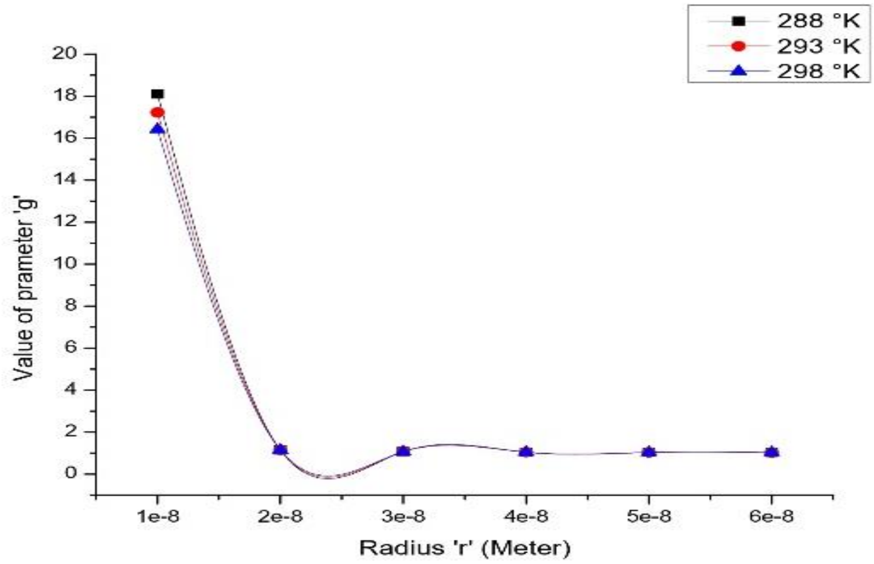
$$N_0 = \phi$$
$$or$$
$$N^{(P)} = N_0 \exp\left(-\frac{p^2 e^2}{8\pi\varepsilon_0 rkT}\right)..(21)$$

Ignoring multiple charges, the ratio of uncharged to charged nuclei is given as

$$\frac{N_o}{N} = g = exp\left(\frac{p^2 e^2}{8\pi\varepsilon_0 rkT}\right) \dots\dots\dots\dots\dots\dots\dots\dots\dots (22)$$

Table-2 Variation of the parameter 'g' with temperature 'T' and r in meter.

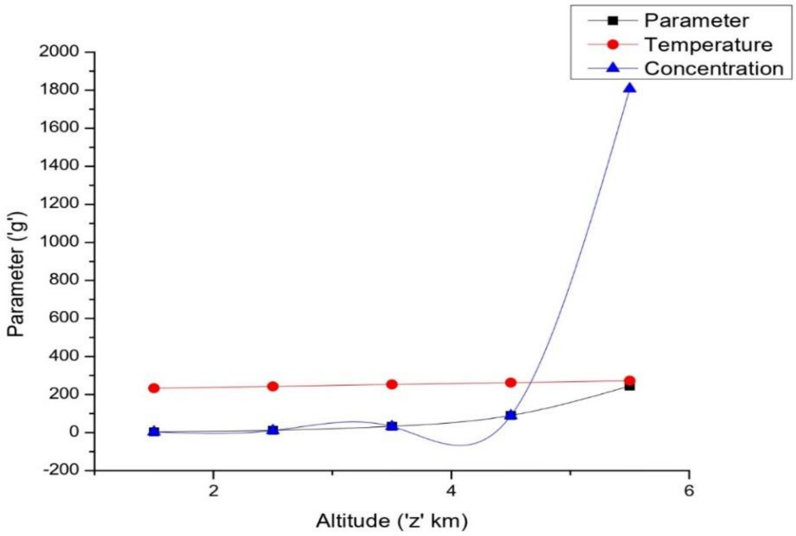
S.No.	r in meter	$g = \exp\frac{(1.6)^2 \times 10^{-38}}{8\pi \times 8.85 \times 10^{-12} \times 1.38 \times 10^{-23} \times rT}$		
		$T=288^0K$	$T=293^0K$	$T=298^0K$
1	1×10^{-8}	18.1	17.23	16.42
2	2×10^{-8}	1.15	1.15	1.15
3	3×10^{-8}	1.07	1.07	1.07
4	4×10^{-8}	1.05	1.048	1.047
5	5×10^{-8}	1.037	1.036	1.035
6	6×10^{-8}	1.029	1.029	1.028



Graph1: Variation of the parameter 'g' with temperature 'T' and r in meter.

Table-3: Variation of the parameter 'g' with temperature 'T' and altitude.

S.No.	Altitude 'z'(km)	Concentration N_0/N	Temperature 'T'	Parameter 'g'
1	1.5	4.48	233	3.48
2	2.5	12.18	243	11.18
3	3.5	33.11	253	32.11
4	4.5	90.01	263	89.02
5	5.5	244.69	273	1807.80



Graph2: Variation of the parameter 'g' with temperature 'T' and altitute 'z'

Table (2) gives the values of parameter 'g' calculated from equation (3) for different sizes of aerosol and Temperature. It is clear from this table that for particles of radii less than $5\text{x}10^{-8}$ m, charges in the radius will be effective in the determination of value of g. The effect of change in temperature by 10^0C on g for the same radius of particles is negligible.

To bring an approximate relation between small ionic concentration, value of g and total particles concentration, we assume equilibrium condition and n_1=n_2=n and N_1=N_2=N.

From equation (9) and (10) we obtain for small ions of one kind

$$\frac{q-\alpha n^2}{n} = N(\eta + \eta_0 g) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

By using equations (18) and (22) we get

$$\frac{q-\alpha n^2}{n} = \mu \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Where

$$\mu = A\left[\frac{\eta+\eta_0 g}{2+g}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (25)$$

$$\therefore \quad n = \frac{-\mu \pm (\mu^2 + 4\alpha g)^{1/2}}{2\alpha} \ldots\ldots\ldots\ldots\ldots (26)$$

The negative sign is meaningless (because it gives negative ionic concentration).

Case of Clean Atmosphere:

For a clean atmosphere in which the particulate matter is negligible, μ=0

$$\therefore \qquad n = \sqrt{q/_{\alpha}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27)$$

The unipolar conductivity is given by

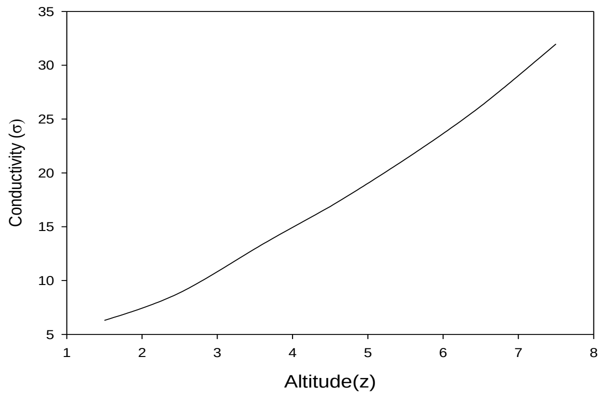
$$\sigma = \omega n e = \omega e\sqrt{q/\alpha}$$

Where

ω, is the mobility of ion.

q, is the ionisation rate,

And α, is coefficient of recombination between small negative and positive ions.



Graph-3.1:Variation of conductivity(σ) with altitude (z)

The conductivity decreases with snow cover on ground as compared with clear ground. Such reduction in conductivity of atmosphere is due to reduction in radioactive emanations from the soil. The conductivity increases with precipitation because the radioactive aerosols and condensation nuclei attached to the precipitation particles.

The values of q have been calculated using the relation,

$$q = 10^{4}(0.48\sigma_{+}^{2} + 110\bar{A}\bar{\sigma}_{+}) \ldots\ldots\ldots\ldots\ldots (28)$$

Where σ_+, is the conductivity due to positive ions.

Assuming charge to be concentrated at the centre or the earth, the variation of electric field for the charge free space is given by-

$$E(r) = \frac{B}{r^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (29)$$

Where B, another constant. The electric field decreases with height approximately as

$$E(z) = E_0 e^{-yz} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

Where y, is the constant depending on the local conditions. (Israel) [19].

The pair production rate of the ions is due to cosmic rays and radioactive substance. The ionization rate due to radioactive substance above the land surface, decreases exponentially with altitude z and is given by-

$$q(z) = q_0 \exp\left(-z/_{S_r}\right) \ldots\ldots\ldots\ldots\ldots\ldots (31)$$

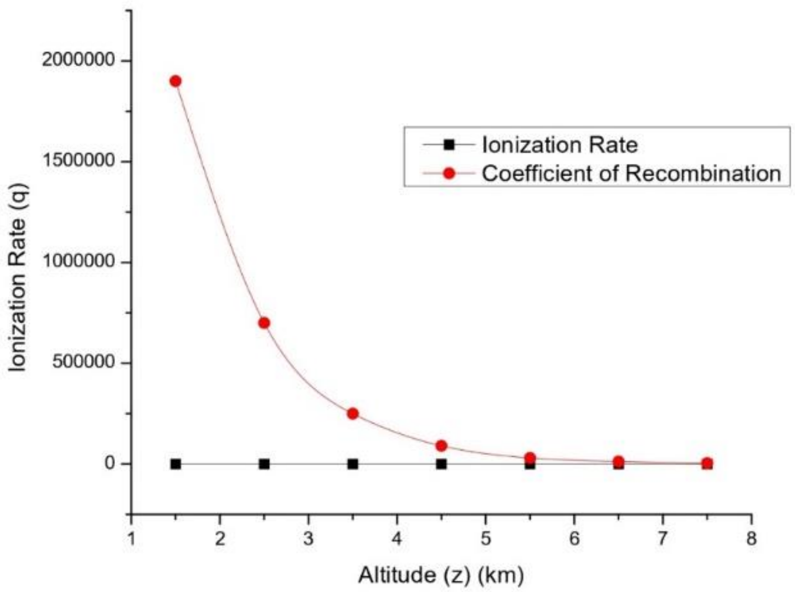
Where (q_0=8.6x10^6 m^3s^{-1}) [90], (S_r=1km) [141] ***a***nd z is the altitude above the sea level.

In polluted atmosphere the value of n, the number of ions is given by-

$$n = \frac{-A(\eta' + \eta_0 g) + [A^2(\eta' + \eta_0 g)^2 + 4\alpha q(2+g)^2]^{1/2}}{2\alpha(2+g)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (32)$$

Table-4: Coefficient of recombination and Ionization rate in clean atmosphere.

S.No.	Altitude (Km) (z)	Coefficient of Recombination (α)	Ionization Rate(q)
1	1.5	1.3×10^{-5}	1.900×10^{6}
2	2.5	1.2×10^{-5}	0.700×10^{6}
3	3.5	1.0×10^{-5}	0.250×10^{6}
4	4.5	0.9×10^{-5}	0.090×10^{6}
5	5.5	0.8×10^{-5}	0.030×10^{6}
6	6.5	0.7×10^{-5}	0.012×10^{6}
7	7.5	0.6×10^{-5}	0.004×10^{6}



Graph3: Coefficient of Recombination and Ionization rate in the clean Atmosphere

For positive small ions Chalmers suggests the values

$\eta_{12} = 4.6 \times 10^{-12} m^3 sec^{-1}$

$\eta_{10} = 41.8 \times 10^{-12} m^3 sec^{-1}$

$\alpha = 1.6 \times 10^{-12} m^3 sec^{-1}$

Table (4) shows the variation of concentration of small ions with g for different values of ionization rate. It is clear that the variation of small ion concentration with g is not considerable. Assuming that 40% of condensation nuclei are charged over land areas as suggested by Israel we get

A= 5N

$$\therefore \quad n_{ionic} = \frac{-10^{-6}A + [(10^{-6}A)^2 + 1.6q]^{1/2}}{1.6 \times 10^{-6}} \ldots\ldots\ldots\ldots\ldots\ldots (33)$$

Equation (33) shows variation of small ionic concentration with condensation nuclei and ionization rate. It can be concluded that aerosol concentration and radioactive content are two factors which predominantly influence the diurnal course of small ion concentration (and conductivity).

Behavior of Conductivity after Precipitation:

There exist many reports in the literature on the behavior of conductivity during the precipitation. Since the radioactive aerosols and condensation nuclei attach to the precipitation particles the electrical conductivity increases during the precipitation. Especially, compared to fair weather values during the thunderstorm rain conductivity increases because of additional factor increased ionization due to lightning and point discharges. However, not many, but few reports exist on the behavior of conductivity after heavy spell of rain.

To make sure of these points we have calculated q by using equation (30) with a procedure which we have done previously for calculating q for different snow conditions. The calculated values of q suggest continuous increase of ionization rate with the passage of time irrespective of what is happening with condensation nuclei when the rain got abated.

Conclusions:

From above calculations, it can be concluded that charged cloud and precipitation particles in thunderstorms can cause electrical conductivity 1 or 2 orders of magnitudes higher that the conductivity in clear air at the same level. The value of this conductivity increases with rate of precipitation, liquid water content, electrical charges on the particles and the electric field. If the cloud and precipitation particles are preferentially charged and are unevenly distributed in thunderstorms, as is most likely to be the case, then both polarities of conductivity also may separately show the relaxation times for the and time. A unique feature of conductivity caused by cloud and precipitation particles is that in spite of its high values, the corresponding relaxation time of the cloudy air for the existence of space charges may not necessarily be small this being especially so for small pockets of space charge and for the individual charged particles. This effect is now recognized and included in the calculations of the ambient electric field caused by the growth of the main charge centers of the thunderclouds [21][16] [1]. These findings corroborate the results of [17] that the charge and regions of powerful electric fields appear to be confined in relatively small volumes and that they are not widely distributed in thunderclouds. These cloud and precipitation particles may be charged either by ionic diffusion and collection or due to any of the charge generating process suggested for the electrification of the thundercloud.

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