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Numerical Simulation of Electric Field and Charge Structure within an Isolated Thunderstorm

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Abstract
The study of electrical structure of thunderstorm is a deterministic factor in characterizing the behavior of lightning. It is impossible to measure the value of electric field at every point within the thunderstorm, even when the *in situ* measurements are made, they are done along the path of balloon-borne instruments or other methods employed in the measurement. The average data obtained from past measurements were employed in determining the electric field generated by the thunderstorm as observed along the horizontal distance using the cylindrical charge model. The data consisted of a screening charge layer firstly located "between" 1.8-2.0 km and later between 10.0-10.2 km respectively above the ground level (agl) to see the effect of positioning on the resultant computation. The lower positive charge center with radius ranging from 0.5 km to 2.0 km was placed at various heights between 2.0 and 6.0 km. This is to determine the effect of cloud base height on the resulting field profile. The main negative charge is accommodated between 4.0 and 7.5 km and the upper positive charge layer existed between 7.5- 10.0 km agl for a cloud base height of 2.0 km and 6.0- 9.5 km agl for a negative charge layer, 7.5- 11.0 km agl for upper positive charge with a cloud base of 4.0 km high. The resulting potential gradient (PG) profiles were obtained for spatial distribution with screening charge layer playing no active role in the thunderstorm electrification. The effects of wind shear due to increasing wind speed with height were also investigated to have a clear picture of the cloud charge dynamics; hence the vertical PG patterns produced by a moving thunderstorm for various cloud cell life-times were modeled. The results showed that a typical tropical thunderstorm can exhibit charge layer more than the normal tripolar structure, and the pocket of lower positive charge can be more than one or larger than the usual size. Wind shear was found to enhance lightning discharges at the surface of charge discontinuities.
Keywords: Potential gradient, Wind shear, Cloud charge, Lower positive charge center, Noninductive charging.

Introduction

Most of the studies conducted in atmospheric electricity were concentrated on the vertical distribution of charges and hence the value of the potential gradient. Even the vertical potential gradients values are not exact because the measuring instruments penetrating the clouds are not vertical positioned rather in most cases were slanted. But in natural clouds large horizontal components are known to occur and hence the horizontal effect of electric field needs to be well understood. Values of horizontal component of potential gradient up to about 100 kVm^{-1} have been reported in literature (Rust and Moore, 1974 and Winn et al. 1974). Stanford (1971) concluded from the analysis of electromagnetic noise data from thunderstorms that in-cloud electric fields may often have horizontal components three times as large as the vertical ones. Theories concerning the mechanism of thunderstorm electrification have been reviewed. Among the notable authors are Williams (1988), Jungwirth et al. 2005, and Hou et al. 2009. The mechanisms of thunderstorm electrification based on physical principles of electrical and meteorological properties proposed by Latham and Stow (1969), are responsible for both the non-inductive charging mechanism and inductive charging mechanism. The non-inductive charging mechanism is concerned with rebounding collisions between cloud ice particles and riming graupel. The ice particles are growing at different diffusional rates, collide and share charges at high rate. A high degree of electrification is associated with the presence of all the three types of cloud particle namely-ice crystals, rimed aggregates and super cooled droplets. This is consistent with the non-inductive mechanism often called Reynolds-Brook mechanism (Reynolds et al., 1957, and Saunders et al., 1991) while the inductive mechanism relies on the rebounding ice-ice or possibly, ice-water collisions. A moderate electrification is observed when crystals and aggregates are coexisted in the absence of super cooled droplets. The operating mechanism in this case is inductive. The pre-existing vertical electric field may induce charges into uncharged particles that may be transferred during collisions, so that the particles rebound can separate charge and therefore enhanced the field strength (Brooks and Saunders, 1994). These charging processes are the principal mechanisms proposed to explain the electrification of thunderclouds (Soriano et al., 2001). In addition to these two candidates for thunderstorm electrification, the observed hydrometeor charges in traversed thunderstorm are generally consisted of a mixture of both signs. This is incompatible with the inductive mechanism but is explicable in terms of non-inductive mechanism because of the possible role of asymmetric rubbing which controls the sign of the charge transfer (Latham and Miller, 1965). The process may also be important since is connected with the electrical relaxation time of the earth's atmosphere and the particle's dielectric and physical properties that permits the charge transfers in the available contact time. The relaxation period allow the charges to remain on the particle long enough for regions of high electric fields to develop in the cloud volume. Past studies have shown that charging mechanism may be the best approach to the study of charge distribution in a thunderstorm (e. g., Takahashi and Keennan, 2004). Apart from the charging mechanism, the initiation of lightning seems to be associated with the developments of robust ice phase (Chauzy et al. 1985, and Carey and Rutledge, 1996). In fact, numerous observations referred to the presence of precipitation-size ice in lightning producing clouds (Petersen et al. 1996, and Soriano et al. 2001).

The reviews of these theories have supported the idea that the thunderstorms commonly exist as a dipolar or tripolar electrical structure. When the charge structure consists of a main midlevel negative charge region, with a positive charge above and a small pocket of positive charge region below, this arrangement is often referred to as the normal tripole (Williams, 1988). The present study concerning lower positive charge usually requires either inductive charging of precipitation below the roughly -10^{0}C isotherm after the lower negative charge region is well established or noninductive charging of precipitation below the roughly -10^{0}C to -15^{0}C isotherm (Goodman et al. 1988 and MacGorman et al. 1989). Rust and Marshall (1996) argued that the current tripole models are too simplistic to apply to all mature thunderstorms and mesoscale convective systems. MacGorman et al. 1989, proposed an 'elevated charge mechanism' to explain the lightning characteristics in the severe storms, based on a normal electrical structure and found that a negative screening charge layer is situated near the upper cloud boundary. Zheng et al. 2010, hypothesized that the main negative charge level is raised to a high altitude by the strong updraft in the severe storms, and this resulted to an increase in height of the base of the negative charge and the ground. They concluded in their findings that the closer the negative charge region to the upper positive charge region the more readily the inter-cloud (IC) flashes is produce between the two, which could explain the high frequency of IC flashes in severe storms. Stolzenburg et al. 1998c obtained a complex charge structure which consist of four main charge regions near the updraft, with differences in the heights and temperatures at which the charge regions were located. For example, the centers heights of the main negative charge region averaged 9.1 km (-22^{0}C) in supercell updrafts, 6.9 km (-16^{0}C) in mesoscale convective systems (MCS) region updrafts, and 6.0 km (-7^{0}C) in New Mexico mountain storm updrafts. Also, outside the updraft in the convective precipitation, six charge regions were found with the center of the main negative charge region is at lower altitude and warmer temperature (average 5.5 km, -6.2^{0}C) than with the case of updrafts. In some thunderstorms, it has been reported that the electrical structure changes with development of the storm (Wiens et al. 2005). From the results of two multicellular storms observed during STEPS project, Tessendorf et al. 2007, observed that one of these storms exhibited a normal tripole charge structure, while the other exhibited inverted polarity charge structure. Most of the inferred charge regions outside updrafts are shallower and have larger charge densities. Stolzenburg et al. 1998c suggested that the noninductive charging (Saunders et al. 2006) mechanism could explain the tripole structure in the updraft, but additional processes such as inductive charging, lightning deposition of charge (as described by Marshall and Winn, 1982), screening layer production might be important in the strong electric field of the nonupdraft regions and cloud contribute to the more complex charge structure observed there. The observations of inverted polarity storms were carried out by the Severe Thunderstorms Electrification and Precipitation Study (STEPS 2000), inverted charge structures of opposite polarity to the normal charge structure configuration was obtained. The charge structure has a main midlevel region of positive charge, and negative charge above and below, in an alternative pattern. Hence, within a convective system, the numbers of charge layer may be more at a location of the storm than the other locations. This confirms the suggestion that more complex charge configurations occur within thunderstorms of a convective system (Marshall et al. 1995; Rust and MacGorman, 2002, Rust et al. 2005 and Zhang et al. 2006a). It is evident based on the data collected using electrical soundings, that there is direct correlation between updraft and the height of the charge level (Stolzenburg et al., 1998a, b). Williams (1988) in his own contribution suggested that the tripole is adequate to describe the basic thunderstorm charge structure and the inverted charge structure, may be conducive to producing positive cloud to ground (CG) lightning. Charge configurations hypothesized to be favorable for producing positive CG flashes including tilting of the charge layers due to wind shear, precipitation unshielding of positive charge (i.e., fallout of a lower-level negative charge region revealing the upper positive charge) feedback formation of a lower charge region based on the convective charging mechanism of Vonnegut (1963), the formation of a small lower negative charge below positive charge, and inverted-polarity storm electrical structure (Williams 2001 and MacGorman et al. 2005). The charge structure typically associated with negative CG producing storms is often referred to as a ''normal'' tripole. Several studies suggested that in normal storms, the lower positive charge region is required to produce negative CG lightning (e.g., Jacobson and Krider 1976; Williams et al. 1988). The model simulations of storm electrification by Mansell et al. 2002 also suggested that the lower negative charge regions may be necessary for negative CG flashes, consistent with the observations of Wiens et al. (2005). Hence, lower negative charge may play a role in the production of negative CG flashes.

Various modifications to vertical wind profile models have been attempted by Markowski et al. (1998, 2003). It is a common issue that horizontal shear in the wind sometimes decapitates growing cumulus clouds, carrying away the portion of the cloud containing the best developed rudimentary precipitation particles and thereby preventing or delaying the onset of precipitation. Also shear contributes to the energy available for convection when the cells reach an appropriate size. If the field of completion is characterized by vertical wind shear, a sudden jump in the growth rate of the clouds will appear when they approach the size at which they can utilize the energy of the shear for their growth. Such large shear in horizontal wind with height in combination with a high cloud base may be required for the production of an unusually large fraction of ground flashes lowering the positive charge to ground (e.g. Orville et al. 2002). But in the tropics the jump usually does not occur until a cloud has been precipitating hence the shear energy will contribute vigorously to the selection of the favoured cloud to be developed. A substantial report supports the idea that elevated cloud base heights are conducive to storms with inverted polarity of the main cloud dipole. Carey and Buffalo (2007) noted that the resulting high cloud bases and shallow depth of warm rain processes lead to less precipitation that entered to the mixed-phase region to deplete cloud liquid. Severe storms in the less precipitation supercell category are most likely to show inverted polarity and hence low production of rainfall. The role of cloud base height may enhance the flash rate of tropical continental thunderstorms (Williams et al. 2005). High cloud base and shallow warm cloud layer may delay or lessening the electrification needed to produce the lower charge region (MacGorman et al. 2011).

Cylindrical Charge Model

In this research work we shall numerically cut a thundercloud in form of cylindrical slices horizontally and then build it up by combining the electric field effect of each slice together to obtain the electric field resultant –an artifice which facilitates investigations of the effects of volume distribution of charges both inside and outside the cloud (Krehbiel et al. 2008 and Falade and Adesanya, 2014). Falade and Adesanya, 2014 considered a vertical cylindrical charge volume of radius a, with ends at height h_1 and h_2 in a cylindrical coordinate system (r,θ,z) in which the z-axis coincides with the axis of the cylinder which originated from the ground. The results obtained

$$F_{z-0}=\frac{2\rho a}{\pi\varepsilon_0}\left[\frac{\pi h}{2a}-\int_0^{\frac{\pi}{2}}\frac{a+u\cos 2x}{\chi^2}(h^2+\chi^2)^{1/2}dx\right]_{h_1}^{h_2},\quad u<a \qquad \text{........(1a)}$$

$$F_{z=0}=\frac{2\rho a}{\pi\varepsilon}\left[\int\frac{a+u\cos 2x}{\chi^2}(h^2+\chi^2)^{1/2}dx\right]_{h_1}^{h_2},\quad u>a \qquad \text{.......(1b)}$$

$$F=\frac{2\rho a}{\pi\varepsilon_0}\left[\frac{\pi h}{4a}-\int_0^{\pi/2}\frac{a+u\cos 2x}{\chi^2}(h^2+\psi)^{1/2}dx\right]_{h_1}^{h_2},\quad u=a \qquad \text{......(1c)}$$

where, ρ is the constant charge density in the cylinder, and ε_0 is the permittivity of free space. Equation (1) can be normalized in the form

$$F=\frac{2\rho a}{\pi\varepsilon_0}\left\{\left[\Omega\left(\frac{u}{a},\frac{h}{a}\right)\right]_{h_1}^{\infty}-\left[\Omega\left(\frac{u}{a},\frac{h}{a}\right)\right]_{h_2}^{\infty}\right\} \qquad \text{...... ... (2)}$$

In tropics, the space charge and in-cloud charge densities in thunderstorms are of the order 10^{-9} C/m^3. Based on the average data obtained by Marshall et al. 2001, Wiens (2005), and Tessendorf et al. 2007 values of charge densities were assumed for a volume of cylindrical slice of the cloud. MacGorman et al. (2014) inferred from a vertical structure of charge, a stack of alternating charge polarities, with the lowest region of large charge density, $|\rho|\geq 0.5$ nCm^{-3}, being a negative layer near or just above the melting layer. Based on the past reports, it appears that the mixed phase region (main charge generating mechanism) in a typical thundercloud is located within a cylindrical slice at a height of about 5 km above the ground (Shepherd et al. 1996). Zhang et al. (2014) found the charge density of the middle negative charge larger than the lower and upper positive charge regions. Hence, the model charge densities are assumed to decrease in both directions from a maximum around a height of 5–6 km. The computed data is obtained by dividing the cloud volume into cylindrical slices within which the charge density is assumed constant. Therefore, we shall consider first a stationary anvil thundercloud model of height 10 km and a radius of 9 km and 7.5 km for the upper positive charge ranged between7.5 to 10 km. The charge densities were varied between 0.7 nC/m^3 and 0.6 nC/m^3 within the upper positive charge layer. The mid-negative charge region is located between 4-7.5 km with a base radius of 5 km and charge density of 0.8 nC/m^3 and 0.7 nC/m^3 for heights 4-6 km and 6-7.5 km respectively. The lower positive charge of radius 1 km and charge density, 0.5 nC/m^3 is located between the heights of 2 km and 4 km as shown in fig. 1a. The electric fields aloft, near cloud base, were often twice the intensity of the surface fields and had large horizontal components that indicated non-uniform distributions of charge (Rust and Moore, 1974). This may be due to screening charges located below the thundercloud. Qie et al. 2005 obtained a lower cloud boundary charge region of about 0.2 km, acting as a screening charge layer below a thundercloud. A negative screening charge layer of 0.2 km is placed in the lower boundary of the thundercloud with charge density, 0.3 nC/m^3. With cloud space charge density ρ_c and screening charge density ρ_s taking into consideration, the profile of the potential gradient (PG) distribution against horizontal distance, u generated from a tripolar structure of fig. 1(a) with screening charges located below the thundercloud compared with tripole of fig. 1(b) without screening charges is shown in fig. 2(a). Fig. 2(b) is the comparison between a tripolar with screening charge layer and upper dipolar structure. Similarly, other computations were made using the same value of charge density, but the position of the negative screening charge layer is now raised above the upper positive charge, a PG profile depicted in fig. 2(c) resulted from the comparison between the position of screening charges located below and above the thunderclouds respectively. Fig. 2(d) depicted the profile of PG resulted from a thundercloud with screening charge layers of 0.2 km thick located at the top and bottom compared with tripole of fig. 1(b). The effect of screening charges on the resultant field forming around thundercloud boundaries is likely to be neglegible as evident from fig. 2, but the screening charges can reduce the net charge content in the upper charge region of a tall thundercloud because of the variation in atmospheric conductivity. It can also magnify the local electric field near the cloud boundary through the formation of extra charge layer particularly at the top of the thunderstorm which explains the development of the blue jets (Krehbiel et al. 2004).

The role of high cloud base were also computed, where the base of the thundercloud of fig. 1(b) were raised to 4 km above the ground. The resultant field obtained in comparison with a normal thundercloud base of 2 km is shown in fig. 3(a). A positive PG spike were observed at horizontal distance, $u =$-9 km guarantee the positive charging of the large ice particles according to the laboratory studies. This feature has been attributed the adiabatic cloud water content in moist convection (Williams et al. 1991). There is tendency for suppressed warm rain coalescence with a higher cloud base to allow more cloud water to access the mixed phase region was reported by MacGorman et al, 2011. Fig. 3(b) was obtained from the comparison between high cloud base of tripolar and upper dipolar structure. The results of Simpson and Scrace (1937) and Marshall et al. (1982), showed an evidence of one or more localized regions of positive charge in the base of the cloud. MacGorman et al. (2014) found from the analysis of vertical electric field profile, a region of relatively small positive charge density just below the negative layer and another region of even smaller positive charge density at roughly 2.5 km mean sea level (MSL). Blanchard (1966) and Iribarne and Mason (1967) established that the charge separation resulted from the bursting of air bubbles released from the ice during melting may be responsible for the spatial concentration of charge (pockets of positive charge) located in the bases of many thunderstorms below the 0^0C level and the break up of large raindrops and the capture of positive ions from the point discharge stream may also contribute. Presently, it is believed that having enough lower positive charge usually requires either an inductive charging of precipitation below the temperature of about -10^0C isotherm after the midlevel negative charge region or noninductive charging of frozen precipitation below the temperature of about -10^0C to -15^0C isotherm (Goodman et al. 1988 and MacGorman et al. 1989). Hence, the effect of the pocket of lower positive charge with radius of 1 km were computed and compared with when the radius is increased to 2 km, a more positive field were obtained with radius of 1 km as shown in fig. 3(c). When the 2 km radius of lower positive charge layer were compared with combination of pockets of three lower positive charge of radius 0.5 km at interval of 0.5 km from each other, a feature of interest were obtained as shown in fig. 3(d) with a number of humps appeared in the PG profile which describes the charge distribution in real clouds.

Potential Gradient below a moving Thundercloud

Contrary to the potential gradient patterns below thundercloud modeled with volume charge distributions as in described in Falade and Adesanya (2014), thunderclouds are normally in motion, thus a moving thundercloud gradually undergoes continuous changes in its profile on account of wind shear. Wind sometimes decapitates growing cumulus clouds, carrying away the portion of the cloud containing the best developed rudimentary precipitation particle and thereby preventing or delaying the onset of precipitation. Wind shear can also contribute to the energy available for convection when the cells reach a certain stage. If such stage is characterized by vertical wind shear, a sudden jump in the growth rate of the clouds will appear at the point when such energy can be utilized for their growth. In tropical region, the jump usually does not occur until a cloud has begun precipitating and the shear energy contributes to the determination of the splited cloud to be favoured vigorous development. The internal circulation within a thundercloud can effectively annul or atimes a low wind shear in the lower region of a cloud (Davies-Jones, 1974). Vigorous cumuli with strong updraughts often continue to grow in volume and height until they encounter a thermally stable layer in the atmosphere that serves as a ceiling on their further development. The stable stratosphere frequently limits the final height of most large cloud systems that many of them go no higher than 9 km to about 12 km above sea level. When a rising cloud parcel encounters a stable layer, its vertical motion is usually deflected horizontally. The cloud top often loses its cumuliform appearance and exhibits a toroidal or flattened top. At times strong horizontal wind occur at cloud top altitudes, these blow the flattened layer of ice crystal cloud downwind, forming a Cb incus or anvil cloud.

The situation considered above is for a stationary thundercloud and hence spatial distribution has been modeled instead of time variation since the thunderclouds are normally in motion as cloud ages. In an atmosphere, wind velocity increases with height and ranges between 2m/s to about 12m/s except in storms which is higher but in most cases not more than 30 m/s (Davies-Jones 1974). Hence we consider the effect of the wind shear on the potential gradient monitored at a particular point p on the ground depending on the direction of the wind, by merely change the horizontal distance u in equation (2) to $d_0 - vt$ when approaching the point p or $d_0 + vt$ when moving away from the it, where v is the mean translational velocity of a cloud cylindrical slice and t is the time in minutes.

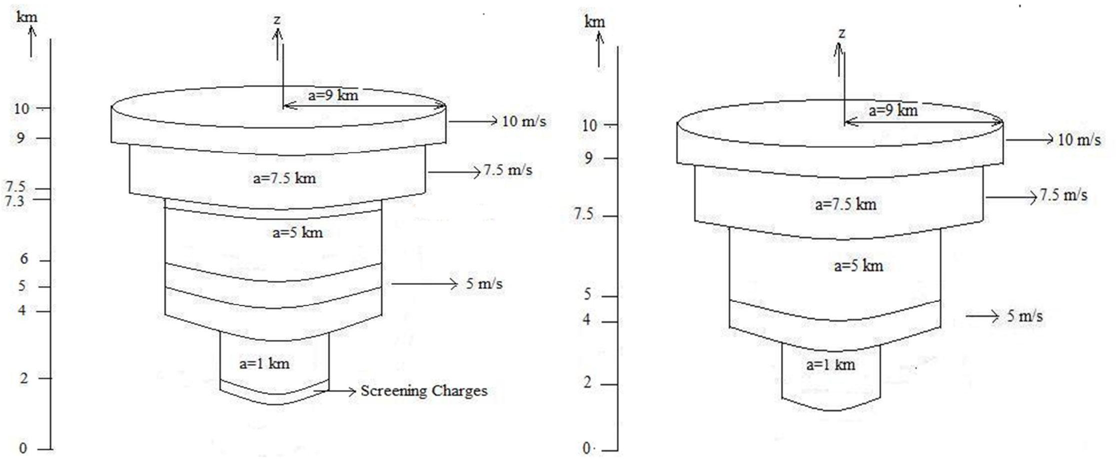

Fig. 1. An anvil thundercloud Model

Equation (2) can now be expressed as

$$F = \frac{2\rho a}{\pi \varepsilon_0}\left\{\left[\Omega\left(\frac{d_0 - vt}{a}, \frac{h}{a}\right)\right]_{h_1}^{\infty} - \left[\Omega\left(\frac{d_0 - vt}{a}, \frac{h}{a}\right)\right]_{h_2}^{\infty}\right\} \quad \text{for } u = d_0 - vt \qquad (3a)$$

Or

$$F = \frac{2\rho a}{\pi \varepsilon_0}\left\{\left[\Omega\left(\frac{d_0 + vt}{a}, \frac{h}{a}\right)\right]_{h_1}^{\infty} - \left[\Omega\left(\frac{d_0 + vt}{a}, \frac{h}{a}\right)\right]_{h_2}^{\infty}\right\} \quad \text{for } u = d_0 + vt \qquad (3b)$$

By employing the computations directly at a point corresponding to the center of the cloud in equation 3(b), $d_0 = 0$. Then

$$F = \frac{2\rho a}{\pi \varepsilon_0}\left\{\left[\Omega\left(\frac{vt}{a}, \frac{h}{a}\right)\right]_{h_1}^{\infty} - \left[\Omega\left(\frac{vt}{a}, \frac{h}{a}\right)\right]_{h_2}^{\infty}\right\} \quad \text{for } u = vt \qquad (4)$$

Time values for storms were varied between 0 and 90 minutes since potential gradient pattern encountered during the thunderstorms are usually less than an hour. Also the assumption that the charge densities in the slices of the cloud remain constant throughout the life-time of the cloud is considered. The potential gradient profiles are depicted in fig. 3(c) for various cloud slices with their respective speed as shown in fig. 1(b). When the speed of the lower positive charge was changed from 2.5 m/s to 5 m/s the profile of the potential gradient assumed another shape as shown in fig. 4(d). This is a confirmation that wind shear has much effect on an isolated thunderstorm.

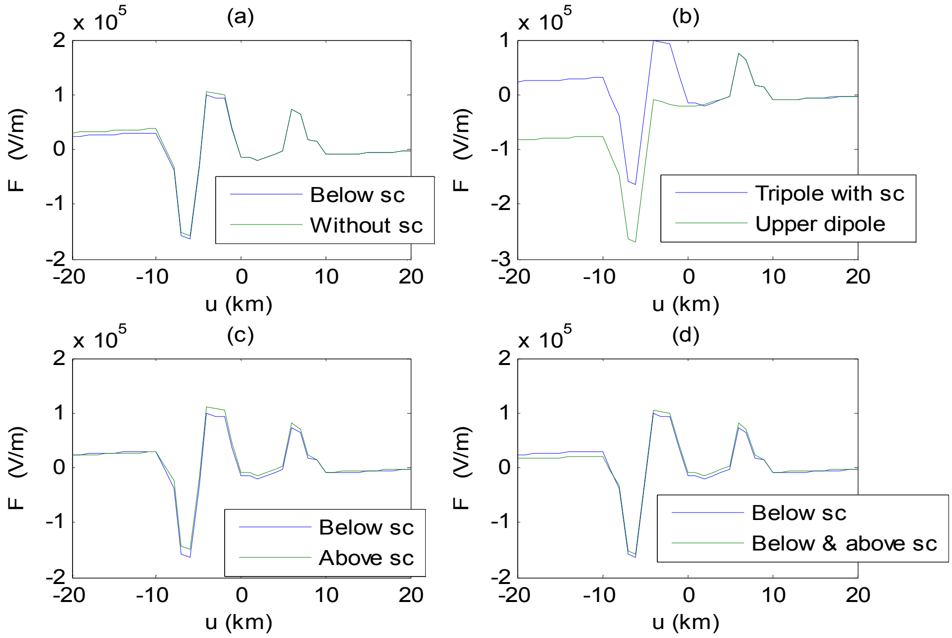

Fig.2. Potential gradient profile (a) comparison between normal tripole thundercloud model of fig 1(a) with screening charges (sc) located below it and fig. 1(b) without sc, (b) comparison between tripole with sc and upper dipole, (c) comparison between sc located above a tripole thundercloud with the one below it and (d) comparison between the sc charge located below a tripole thundercloud with sc present above and below the thundercloud.

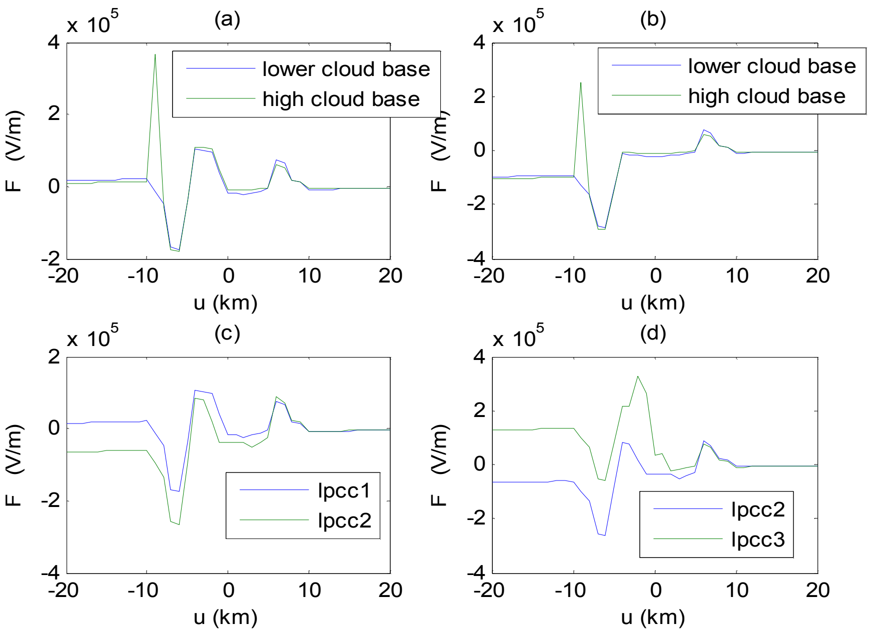

Fig. 3. Potential gradient profile with cloud base raised to height of 4 km compared with the cloud base of 2 km (a) a tripole thundercloud model, (b) upper dipole (c) a tripole of 1km radius, designated with lpcc1 compared with 2km radius, desgnated as lpcc2 (d) comparison between lpcc2 and with combination of three lpcc of radius 0.5 km at interval of 0.5 km from each other, designated as lpcc3.

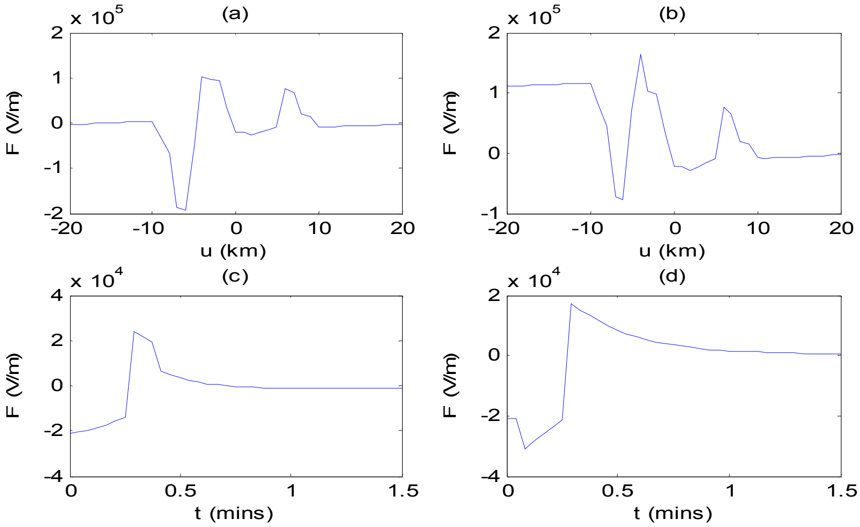

Fig. 4. A normal tripole thundercloud model (a) consisting of single lower charge center, (b) consisting of two lower charge center at an interval of 1 km to each other, (c) a moving thundercloud of fig .1(b) with lpcc moving at speed of 2.5 km/h and (d) a moving thundercloud shown in fig .1(b) with lpcc moving at speed of 5 km/h.

Horizontal wind shear with height in combination with a high cloud base has been described to be a requirement for the production of an unusually large fraction of ground flashes lowering the positive charge to ground (e.g. Orville et al. 2002). Several investigators have suggested that the configuration of charge that initiates a ground flash typically consists of a midlevel charge region above a lower charge of opposite polarity. This arrangement increases the electric field below the midlevel charge in a direction causing lightning propagation toward ground (MacGorman et al. 2005 and Coleman et al. 2008). Qie et al. (2005) reported that a large lower positive charge prevents negative cloud ground flashes from occurring and facilitates inverted intracloud flashes. The values obtained from computation showed that for a thundercloud of height 10 km, base radius of 5 km and base height of 2 km, the lower positive pocket charge radius may be in range of about 0.3 km to 2 km. These values are within the range encountered in the past measurements (e.g., Simpson and Scrace, 1937; Qie et al. 2009 and MacGorman et al., 2014). Various values of charge densities were employed in the calculation (though the lower positive charge is concentrated within the small region of the thundercloud) but the results show that its maximum value cannot exceed the charge density in the middle and upper charge layers which is in agreement with measured values. Several investigators have suggested that the configuration of charge that initiates a ground flash typically consists of a midlevel charge above a lower charge of opposite polarity. This configuration increases the electric field below the midlevel charge in direction causing lightning propagation toward ground. Because the lower charge region often contains less charge than the midlevel charge region and so produces a shallower potential well, hence the downward propagation of lightning may not stop in the lower charge, but may continue to the ground (MacGorman et al. 1989). It is interesting to note that these profiles are similar to the ones obtained in the dipole structure except at early stage of development i.e. about 10-15 minutes when the cloud is developing. The discrepancy in the early stage may not be true in the real cloud as clouds normally develop through a period called transient period before reaching the mature stage. The results obtained from the PG profile with screening charge layer which resulted from the non-continuous electric conductivity at the cloud boundary, does not appear to play an active role in thunderstorm electrification. This also confirmed the past simulations. The screening charges can reduce the net charge content in the upper charge region of a tall thundercloud because of the variation in atmospheric conductivity. It can magnify the local electric field near the cloud boundary through the formation of an extra charge layer particularly at the top of the thunderstorm which explains the development of blue jets (Krehbiel et al. 2004). The high value of field usually observed below the normal thunderstorm may be due to the effect of screening charges.

Conclusion

Both non-inductive and inductive charging processes have been proposed to explain electrification of clouds while the charge separation processes leading to lightning are not fully understood. It is widely accepted (based on wealth of laboratory evidence together with in situ measurements of thunderstorms) that the initiation of lightning seems to be associated with the development of a robust ice phase. The lower positive charge have been reported in literature as essential ingredient for the initiation of CG lightning. The explanation of a persistent positive charge on precipitation in the lower parts of electrified clouds is based on charge reversal microphysics, whereby graupel particles take on positive charge beneath the main negative charge and form a well defined lower boundary to the negative charge region (Takahashi, 1978). The reversal microphysics has been associated with tornadic storms which generate vortex. A numerical model capable of simulating tropical charge cloud has been described together with examples in an unsheared and sheared environment. It has been shown that the vertical potential gradient at a point on the ground at a distance u from the cloud axis is not zero but a reversal distance at which the potential gradient changes sign, it is the boundaries of the cloud charges. These points signify boundary between layers, which past studies have presented strong evidence that the low-level boundaries were associated with tornadic storms (Maddox et al. 2003). It was found that the effect of the screening charges is negligible in the resulting profile of the potential gradient. Some characteristics of the ground electric field over the observational site were modeled. The profile showed that the intense and persistent positive electric field on the ground which is unique feature of thundercloud in the tropics (depending on the locality) is due to the widely extended positive charge in the lower part of the cloud while the fast transitions of electric field from negative to positive and vice-versa are mainly the consequence of the positively charged raindrops falling from the cloud base (i.e. precipitation) Qie et al. (2009). When two or more pockets of lower positive charge were incorporated into the computations, there was an increase in number of humps according to the number of pockets of lower positive charge indicating that the lower positive charge may be associated with precipitation. The evidence of negative surface electric field were obtained beneath the larger than the usual LPCC at the base of the storm while positive surface electric field was obtained in the normal type of tripole thunderstorm. This is evident from the profile of PG in fig. 3(c) and (d).

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