Comments on the Exchange Between Kamra and Saunders Concerning the Inductive Charging Mechanism in Thunderclouds

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In their discussion of the effect of the horizontal component of the electric field on the inductive electrification mechanism, Kamra (1978) and Saunders (1978) assume, as is customary, that it has a negligible effect on the trajectory of the falling precipitation particle. That this assumption is not justified when the electric field becomes intense can be shown as follows.

Consider the situation illustrated in Fig. 1 in which a negative precipitation particle of radius r is moving in a negative electric field of magnitude E that makes an angle ϕ with respect to the vertical. Let it be assumed that the particle carries a charge Q given by

$$Q=12\pi\epsilon_0 fr^2E, \qquad (1)$$

where f is the fraction of the equilibrium charge that a particle falling in a vertical electric field can acquire by the inductive charge transfer mechanism. The horizontal component of the electric force F_{EX} is given by

$$F_{EX}=12\pi\epsilon_0 fr^2E^2 \sin\phi. \qquad (2)$$

The vertical component of the electrical force F_{EY} is

$$F_{EY}=12\pi\epsilon_0 fr^2E^2 \cos\phi. \qquad (3)$$

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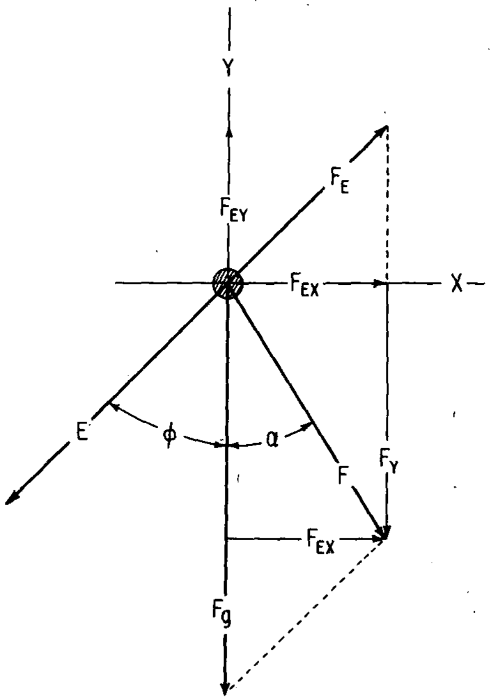

FIG. 1. Forces acting on a charged precipitation particle falling in an inclined electric field.

The net vertical force F_Y is the downward gravitational force F_g minus the upward electrical force F_{EY} or

$$F_Y = \tfrac{4}{3}\pi\rho g r^3 - 12\pi\epsilon_0 f r^2 E^2 \cos\phi, \tag{4}$$

where ρ is the density of the particle and g the acceleration of gravity. The resultant force F, which determines the direction of the particle motion, makes an angle α with the vertical given by

$$\alpha = \tan^{-1}\left(\frac{9\epsilon_0 f r^2 E^2 \sin\phi}{\rho g r^3 - 9\epsilon_0 f r^2 E^2 \cos\phi}\right). \tag{5}$$

TABLE 1. Angular departure of particle trajectory from vertical.

	Electric field (10^6 V m^{-1})					
Drop radius (mm)	1	2	3	4	5	6
0.5	3.5°	16.6°	47°	85°	107°	117°
1	1.7°	7.4°	19°	40°	68°	92°
2	0.8°	3.5°	8.4°	17°	29°	47°

The departure of the trajectories from the vertical of particles having various radii can be calculated by the use of Eq. (5) for arbitrarily chosen conditions. Table 1 shows the angles of departure of the falling drop on the assumptions that the electric field is inclined at an angle of 45° and that the drops carry half of the equilibrium charge.

Saunders' argument, that the charging mechanism is little affected by the horizontal component, is correct so long as the particles fall vertically and the horizontal component of the electric field has no significant effect on their trajectory. This will no longer be true, however, when the particles acquire a horizontal component of motion under the influence of the electric field, for the increased number of collisions occurring on one side of the particle as the result of this motion will act to decrease its charge. The horizontal motion of the charged particle under the influence of the field will have the additional effect of dissipating the electrical energy of the storm. When the product of the horizontal component of velocity and the horizontal component of the electric field exceeds the product of the vertical component of the velocity and the vertical component of the electric field, the falling electrified particle instead of increasing will decrease the electrical energy of the storm.

REFERENCES

Kamra, A. K., 1978: Reply. *J. Atmos. Sci.*, **35**, 165–166.
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