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THE EARTH'S NEGATIVE CHARGE

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The phenomenon of the earth's negative electrical charge, discovered in the eighteenth century, has attracted the interest of many scholars.

In the nineteenth century attention was called to the fact that with a constant loss of charge from the liquid and solid surface of the earth the terrestrial sphere should be discharged over the course of 10 min. After this, intensive studies commenced to determine the mechanism of maintenance of this negative charge.

However, even at present no satisfactory solution to this problem has been presented.

The nature of the generator which continually maintains a negative charge on the surface of the earth has not yet been discovered. It has been generally accepted that in regions of fair weather, due to the conductivity of the atmosphere the earth only loses negative charge, while this loss in compensated in inclement weather regions by supply of negative charge from the atmosphere. Over the course of this century new theories have been put forward continually to explain the nature of the generator which compensates charge loss.

The present study will consider a mechanism for supply of negative charge from the atmosphere. In [1] the term "electrogravitation generator" was introduced, but Frenkel' did not apply the concept to the problem of the negative charge of the earth.

The existence of negative charges in the lower portion of clouds has been confirmed by many investigators (see, e.g., [2]). Under the action of gravitational forces the droplets comprising a cloud are in a state of continuous fall. During the fall from the lower part of the cloud the droplets move into a region of decreased relative humidity, located below the cloud. The drops falling from the cloud carry a negative charge. Evaporating, they transfer this charge to the air. In [1] the process of evaporation of falling droplets was considered, however it was not concluded that ions are transferred into the air volume in which evaporation took place.

The specific gravity of the air beneath the cloud, cooled by evaporation of droplets entering from the lower cloud region, and thus carrying a negative charge, increases. This leads to formation of a descending flow beneath the cloud, which carries negative charges off with itself.

It is such negative charges which Kelvin observed when he detected a potential gradient inversion in the lower layers of the atmosphere up to 30 m [3].

Similar effects were noted at the Eifel Tower in [4]. Chalmers [2] calls attention to the enigmatic nature of these phenomena. He considers the explanation of the maintenance of the earth's negative charge to be one of the major problems of atmospheric electricity.

Both these effects can be explained by descending air flows, made heavy by droplet evaporation and carrying negative charges. The cold air, reaching the surface of the earth, spreads out horizontally and transfers its negative charge primarily to projecting objects, which, when a sufficient charge density is reached, may product a scintillation known as "St. Elmo's Fire." The descending flows below storm clouds may traverse considerable distances, of the order of magnitude of km, and by transferring their negative charges can produce all the known potential gradient anomalies described in [2]. These anomalies are easily observed in mountainous regions near the bases of clouds. In less frequent cases the bottom of a cloud may bear a positive charge. The cold flow descending to the earth will then transfer positive charge. It can be shown that if in a given volume of air there exists a quantity of water in the liquid phase, upon evaporation of this water, i.e., transformation from the liquid to the gaseous phase, the specific gravity of this closed volume will increase significantly.

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We will consider an arbitrary volume of air below a cloud, limited by an imaginary weightless closed shell passing through the gas particles.

In any physical process it is convenient to deal with invariants, i.e., quantities which maintain a constant value as other parameters vary. In the situation under consideration such an invariant is the ratio $\Delta F/mg$, where ΔF is the change in Archimedean force applied to the body under consideration upon evaporation of a droplet of mass m, and g is the acceleration of gravity.

It will be convenient to write the equation of state of the air volume in the form

$$p\Delta V = (\gamma - 1)\Delta E,$$

where E is the internal energy of the gas, $\Delta E = -mq - p\Delta V$, p is the air pressure, ΔV is the change in volume, γ is the adiabatic index, m is the mass of the droplets evaporated, and q is the heat of vapor formation.

Simultaneously with droplet evaporation there is formed a vapor occupying a volume m/ρ_V, where ρ_V is the saturated vapor density. Then the change in the air volume comprises

$$\Delta V_1 = -(\gamma - 1)mq/\gamma p + m/\rho_V. \quad (1)$$

For convenience in approximate calculations we may neglect the second term of Eq. (1). It then takes on the form

$$\Delta V_1 = -m(\gamma - 1)q/\gamma p.$$

Considering that $\Delta F = \Delta V_1 \rho_a g$, where ρ_a is the density of the air at the point of the droplet evaporation, we have

$$\Delta F/mg = -(\gamma - 1)q\rho_a/\gamma p. \quad (2)$$

The invariant $\Delta F/mg$ remains constant for adiabatic compression of the descending air flow. Substituting on the right side of Eq. (2) numerical values of the corresponding quantities, we find $\Delta F/mg = 8$. Thus evaporation of 1 kg of water in an arbitrary volume decreases the Archimedean force applied to this volume by 8 kg.

Two processes occur simultaneously during evaporation:

1) increase in the number of molecules in the gaseous phase, leading to a decrease in specific gravity of the closed volume;

2) cooling of the closed volume due to loss of the heat necessary for evaporation of the water droplets.

Since the second process greatly dominates over the first, the resultant specific gravity of the air volume in which the negatively charged water droplets evaporate increases. This leads to the downward motion of the negatively charged mass of cold air below the cloud, taking the negative ions with it. Estimates show that, due to the low mobility of ions, the electric field of the earth's negative charge produces too small a vertical velocity component compared to the hydrodynamic velocity of the sinking cold air, directed toward the earth in the form of a jet. These air jets, cooled by water droplet evaporation, carry off negative charge from the base of clouds to the earth, and are, essentially, gravitational generators. At a height of several meters above the surface a region with potential gradient inversion develops and the negative charges flow to the surface of the earth.

Thus the cloudy part of the atmosphere supplies the earth by these negatively charged air flows, and compensates the loss of negative charge in regions with clear weather.

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