Application of the Lorentz Force in Directing Atmospheric Events

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***Abstract*— We derive the electric dipole model of cloud condensate in order to demonstrate the Lorentz force exerted on cloud condensate in the presence of the applied electromagnetic field.**

***Index Terms*— Electromagnetics, Atmospheric Physics**

I. Modeling Dipole Moment of Cloud Condensate

The Lorentz force describes the force exerted onto a charge by the electromagnetic field. It is represented with the equation:

$$F = q(E + u \times B)$$

Where q is the charge in Coulombs, E is the electric field intensity, u is the velocity of the charged particle in m/s, and B is the magnetic flux density [1]. All atoms which are electrically charged are candidates for applying electromagnetic fields to induce the Lorentz Force in order to modify their trajectories in space. Atmospheric Events include natural and man-made phenomena creating changes in atmospheric conditions, including cloud formation, atmospheric rivers, electrical storms, and cyclonic storm systems.

The cloud is one of the fundamental atmospheric constituents through which other atmospheric conditions are developed from. Water which is composed of oxygen with polar covalent bonds to two hydrogen atoms which is electrically structured as an electrostatic dipole with a negatively charged oxygen atom and two positively charged hydrogen atoms [2]. Water condensed onto the cloud condensation nuclei form the condensate of the cloud [3]. The water consisting of molecular dipole moments allows us to model the condensate as a polarized dielectric in the presence of the electric field.

$$P = \lim_{\Delta v \to 0} \frac{\sum_{k=1}^{n\Delta v} p_k}{\Delta v}$$

In which P is the Polarization Vector formed by the sum of the dipole moment for each molecule, for the total number of molecules in the infinitesimal volume of the material, where n is the number of molecules per unit volume and Δv is the infinitesimal volume [1]. Each molecular-induced dipole moment is modeled as an electric dipole of two charges $+q$ and $-q$ separated by distance d, with magnitude [4]:

$$p_k = qd$$

In which the direction of p_k is taken as the negative to positive, or from the oxygen to hydrogen atom for the case of water. By taking the sum of each individual dipole moment, we may construct a model of the total Polarization of a condensate particle using the Polarization Vector P with the summation shown above. This then allows us to compose an electric dipole with charge $+q$ and $-q$ separated by distance d which equals the magnitude of P.

With each oxygen molecule modeled as an induced dipole, and the aggregate of oxygen molecules in the cloud condensate modeled as a dipole based on the Polarization Vector, we can now calculate the behavior of cloud condensate in the presence of electromagnetic fields.

II. Behavior of Electric Dipole in EM Field

In the case of a uniform electric field, the positive and negative halves of the dipole experience equal and opposite forces, resulting only in a net torque on the dipole moment. We will now show more generally for an Electric field E, the force on the dipole:

$$F = F_+ + F_- = \Delta F$$

Where F is the total force of the dipole, F_+ is the force on the positive half of the dipole and F_- is the force on the negative half of the dipole. Given an Electric field E we have

$$\Delta F = q(\Delta E)$$

Where q is the magnitude of the charge of one half of the dipole and ΔE is the variation in the Electric field intensity between the top and bottom of the dipole. Using the relation

$$\frac{\partial E_x}{\partial x}\hat{\mathbf{x}} \cdot dx\,\hat{\mathbf{x}} = \partial E_x$$

We may rewrite the above as

$$\Delta E = (d \cdot \nabla)E$$

Where d is the direction from negative to positive of the dipole, which we assume to be infinitesimal, and using the relation $p_k = qd$ [4],

$$F = (p \cdot \nabla)E$$

This gives us the force exerted in the direction of the Electric field onto the dipole. Note for the case of the constant field, $\nabla E = 0$ and the total force is zero. Therefore, the field must have variation for force to be exerted.

We will now repeat the above procedure for the total magnetic force, where

$$F = q(u \times (B_+ - B_-))$$

Using the distributive property of the cross product. We can apply the relation above to retrieve the differential change in the magnetic flux density with $\Delta B = d \cdot \nabla E$ to get

$$F = u \times (p \cdot \nabla)B$$

Combining the equations for the force onto the dipole by the electric and magnetic field, we get the Lorentz Force Equation for the electric dipole:

$$F = (p \cdot \nabla)E + (u \times (p \cdot \nabla)B)$$

Note if magnitude is required we may factor $p \cdot \nabla$ to simplify the expression. What this equation therefore provides us is the ability to determine the force of a molecule which forms a dipole moment such as water in the presence of an electromagnetic field. To further simplify, we will assume the field strength to be strongest at the top portion of the dipole, where ΔE and ΔB are both positive. We may then treat the dipole as a single particle of charge $q = p/d$ where $E = \Delta E$ and $B = \Delta B$ to predict the behavior of the dipole in the field.

III. Application of Electric Dipole Model to Atmospheric Events

As mentioned, the cloud consists of condensate formed as water molecules condense around the condensate nuclei which may be one of a variety of particles, either naturally or deposited in the atmosphere. We apply the Polarization Vector for each condensate by calculating the dipole moments of each water molecule and then apply the Lorentz force equation for the dipole moment modeled by the polarization vector to determine the force exerted on the condensate. With the ability to manipulate the E and B fields using directional antenna systems, we may determine the direction of the condensate. The application of this technique is to determine the movement of cloud systems through the atmosphere, which may contain significant quantities of water which is the case for Atmospheric River systems [5]. The force scales with p which is directly proportional to q and therefore benefits from increase in charge. We therefore propose the investigation of ionization of cloud condensate or storm systems in order to enhance the motive force capability of applied electromagnetic fields for the purposes of directing atmospheric events. This has possibilities in being done by the addition of ionized or charged condensate nuclei in order to induce condensate containing stronger charges, and/or positioning drones with strong high frequency antenna systems to ionize the particles contained within its vicinity for enhanced effect with the applied electromagnetic field through remote directed antenna systems. The usage of existing directed antenna and radar systems is also possible, since the movement of the dipole moment is a property of electromagnetic field interactions which is independent of the source.

IV. Future Work

Investigating the Ionosphere interaction with ground based directed antenna systems generating high power density electromagnetic fields for the purpose of influencing atmospheric events and the solar wind, magnetosphere, ionosphere interaction in atmospheric event movements as supplying solar generated electromagnetic fields as a pre-existing, natural motive force for weather events, in addition to, the long term consequences of man-made manipulation of atmospheric conditions through the direct change in movement of cloud condensate with the application of electromagnetic fields.

References

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