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Modelling of ions for seeding technique to electrify the atmosphere

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ABSTRACT

There are number of ways in which weak electrification can affect the microphysics of clouds, with consequences for cloud lifetime, radiative properties, and precipitation efficiency. Kauffman [2011] suggested ions produced by direct current generators will add to and enhance the catalysing effects that cosmic ray ions are now known to produce in among other things, lowering nucleation barriers, stimulating charged particle growth and stability and increasing the scavenging rate in clouds. Thus to electrify the atmosphere ions can be generated artificially in abundance along with large electric field.

Ions can be generated by the corona effect using Atmospheric electrifiers (a device used to generate negative ions) which makes use of corona discharge phenomenon to charge the air particles. Exact assessment of electric field and charge density distributions and the flow dynamics inside the electrifiers is essential to understand the particle behaviour inside the electrifiers.

In this paper, a novel model of governing equations to evaluate the space charge density, electric field intensity and velocity of ionized airflow is suggested as a function of applied voltage. The Poisson and charge conservation equations are derived and hence can be used to estimate the electric field and charge density distributions. Navier stokes equation can be used to get the velocity of ionized airflow because of electric force on the air. Simulation is carried out to validate the proposed model and verify that velocity is function of input voltage and is proportional to it.

Introduction

Svensmark and Friis-Christensen [1997] and Svensmark [1998] demonstrated correlations of cloud cover with Galactic cosmic rays (GCR) flux, and speculated that ionization processes could affect nucleation or the phase transitions of water vapour. Corona effect ions may have a role in catalysing atmospheric phenomena as suggested by R.G. Harrison and K.S. Carslaw in [2003].S.D Pawar and Kamra [2009] have shown that the space charge released into the atmosphere by corona currents from the ground can increase the air-conductivity of the atmosphere near to earth surface by more than an order of magnitude during the dissipation stage of thunderstorm.

The overall process of natural electrification of atmosphere which is responsible for coalescence and precipitation is summarized [3–11,23] in Fig. 1. There are positive ions and free electrons present in the air as a result of “background radiation” or photon excitation occupying the atmosphere. This natural ionization is emitted from artificial and natural sources, such as radioactive elements and cosmic rays. The majority of the ionization is caused by cosmic radiation where the electric field is high enough. Radon gas released from the Earth's crust can cause radioactive ions to attach to airborne dust and other particles to form aerosols by nucleation. Attached aerosols coagulate to form condensation nuclei which further condense to give cloud condensation nuclei to form cloud. Similar process can be initiated and induced artificially by generating abundance of corona effect negative ions in the atmosphere.

Small ions are produced continuously in the nature. But because of pollution, global warming, the so called modern life style of human beings is responsible and also due to other phenomena; adverse forces tend to destroy these ions as a result of which many natural processes are affected in the atmosphere. The major impact of this is on the natural rainfall hence Ion losses is also the major issue. Thus the actual percent-concentration of the electrons and ions in the free space can be disregarded for this study. The electron avalanche effect because of the artificial ions will ensure an exponential increase of electron generation, which allows for ionization to occur.

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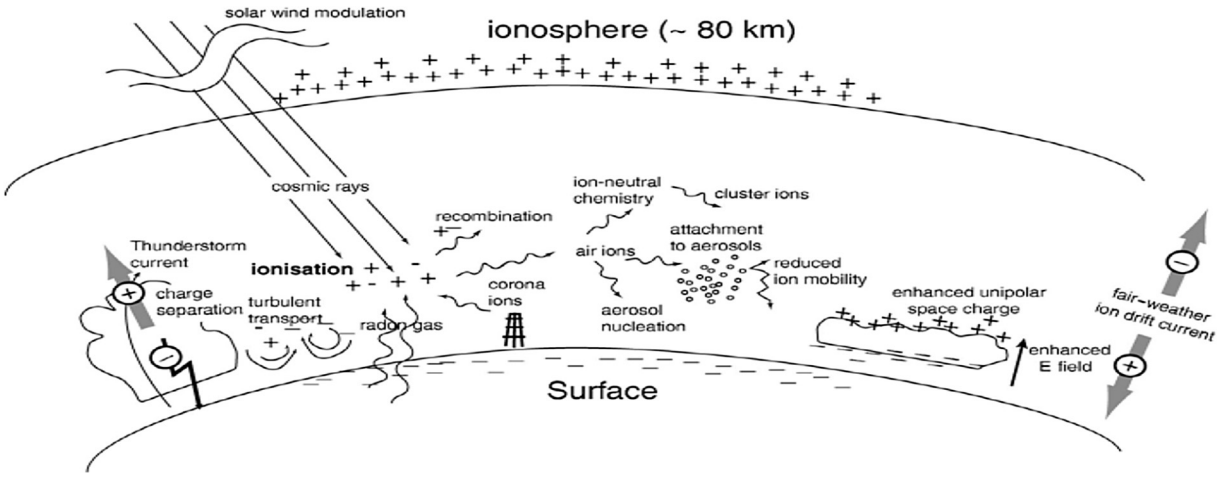

Fig. 1. Role of corona effect ions in catalysing the atmosphere [suggested by R.G. Harrison and K.S. Carslaw in 2003].

When high density uni-polar ions are added in the atmosphere the recombination losses are negligible. As after recombination's with available opposite polarity ions, high density ions act as seed for further reactions with dust particles and droplet coalescence processes. The injection of a large number of DC corona effect ions will induce changes in cloud microphysics and cloud cover and, consequently modifications in weather conditions. It is expected that DC generated ions are going to be a more aggressive catalyser than cosmic rays as corona effect ions are hygroscopic and grow rapidly with increased humidity [1].

Corona effect to generate negative ions

Direct current corona effect ionization starts to occur at ground level. The net effect of ionization will be to charge pre-existing aerosol or form new charged aerosol. Ions produced by direct current generators will add to and enhance the catalysing effects that cosmic ray ions are now known to produce in, among other things, lowering nucleation barriers, stimulating charged particle growth and stability and increasing the scavenging rate in clouds [1]. Thus modelling the corona ions is important as "*clouds can be seeded by ions to produce rain from ground station by electrifying the atmosphere*".

Negative ions are generated using corona discharge phenomenon. Corona discharges are relatively low power electrical discharges that take place at or near atmospheric pressure. The corona is invariably generated by strong electric fields using small diameter electrodes [2] (ion generator and shield electrode). When a negative high voltage exceeding the potential at which corona is found to originate is called corona threshold voltage. When this voltage is applied across an asymmetric geometric model with very small curvature ion generator electrode; because of corona effect the negative ions are generated.

Modelling of an ion

The movement of air particles as a result of the electro hydrodynamic (EHD) phenomenon can be explained through the use of basic physics, including Coulomb's Law of Electrostatics, Conservation of Momentum, and Newton's Third Law.

In order to model the ions for seeding technique to electrify the atmosphere, the governing equations necessary to represent EHD flow induced by corona discharge are described in Section 3.1.

Electrostatic equations

The presence of corona phenomena complicates the mathematical models used to simulate the impact of the electric field and current density distributions in inter-electrode space. Hence a simplified model for analysis of direct current corona field and induced electro hydrodynamic airflow field in atmospheric electrifier system is presented.

Modelling assumptions

The operating voltage range for corona discharge lies between the corona threshold voltage and the air gap breakdown voltage. Corona induced airflow is possible. The gap between ion generator electrodes and grounded electrode can be divided into two regions, the ionization and drift zones. When the ion generator electrode voltage is above the corona onset level, the corona discharge generates the EHD flow. When the radius of the ion generator electrode is much smaller than the distance between ion generator electrode and grounded electrodes, the ionization zone forms a uniform sheath over the coronating region of the ion generator electrode surface. The ionization zone exists in close proximity to the ion generator electrode, in which air ionization occurs, and both positive and negative ions exist. The drift region, located outside the ionization zone, contains ions of a single polarity that have been driven out of the ionization region by the electric field. Columbic force interactions between the ions and the electric field are responsible for ion acceleration.

A simplified model of corona discharge is assumed in this study where the following apply [12–16]:

1. The mono polar corona discharge inside the atmospheric electrifiers is modelled under- All quantities are steady in time and - All ions and particulates are neglected except for those generated by corona discharge.
2. The ion mobility is constant and independent of the electric field's influence.
3. The corona is a discharge where ionization is non-thermal hence thermal diffusion of the ions is neglected.
4. When the flow is at steady-state, space charge density does not change with respect to time.
5. Under standard atmospheric pressure, the EHD flow has a negligible effect on the corona discharge, because the air velocity is much smaller than the velocity of moving ions.