CORONA DISCHARGE IN CLOUDS (OVERVIEW)

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ABSTRACT**:** Overview of literature on the role of corona discharges in formation of Cb characteristics is presented.

INTRODUCTION

Electrical forces in cloud strain a drop in direction of electrical field. This results in increase of electrical field at it poles and leads to drop instability [*Muchnik et al.,* 1982]. There are 2 hypothesis of corona discharge ignition: 1. high energy electrons of cosmic rays ionize air and initiate corona; 2. corona appears as a result of water ejection from precipitating drop where local increase of electrical field take place [*Gurevich, et al.,* 1992]. Crystal also can be source of corona discharge. Discharge starts from its sharp edges.

CONDITIONS FOR CORONA DISCHARGES TO TAKE PLACE IN CLOUDS

Onset electrical field strength E_c to initiate corona discharge depends on drops sizes and is reduced for larger drops [*Nolan,* 1926; *Ausman et al.,* 1967]. It is greater for negative electrical fields in comparison with positive. There is small drops ejection from large one during corona discharge (mostly from its positive pole). It results in positive charging of small drops ejected by large one and appearance of negative charge on large drop [*Macky,* 1931; *Richards et al.,*1971; *Phelps* 1971; *Georgis et al.,* 1997]. E_c is less for horizontal electrical field in comparison with vertical one [*Coquillat et al.,* 1995; *Coquillat et al.,* 1999]. Most experiments and theoretical speculations had shown that onset electrical field to initiate corona from single drop is greater 400-500 Kv/m - maximum possible electrical field in clouds [*Taylor,* 1964; *Griffiths et al.,* 1972; *Latham et al.,* 1977; *Muchnik et al.,* 1982; *Kamra et al.,* 1993; *Georgis et al.,* 1997].

Only large crystals are able to form corona discharges , moreover discharges take place mostly for temperature higher than -18^{o}C [*Griffiths et al.,* 1974a, 1976b; *Abbas et al.,*1976]. Rather small onset fields (100-400 kv/m) are needed to initiate corona discharge from melting graupel and hail [*Muchnik et al.,* 1971; *Dyachuk et al.,* 1979; *Grigoriev,* 1985; *Grigoriev et al.,* 1985; *Grigoriev,* 1987].

Height can significantly reduce E_c due to basic dependence of discharge processes in gases from pressure [*Dawson,* 1969; *Raizer,* 1992]. One can expect corona discharges from single positively charged drops for heights 8 km and higher. Similar results were obtained by *Griffiths et al.* [1974a, 1974b] for crystals. There is decrease in E_c for charged particles [*Miller et al.,*1965; *Sartor et al.,* 1967; *Abbas et al.,* 1969; *Richards et al.,* 1971; *Bourdeau et al.,* 1989; *Coquillat et al.,* 1994]. Positive corona in real clouds can take place from large charged drops even at height 2.5 km (for drop with r=0.5 mm and q=330 pC).

Electrical field strength onset for corona initiation is significantly reduced during drops interaction because there is significant increase in electrical field between approaching drops [*Sartor,* 1967; *Dyachuk,* 1972; *Crabb et. al.,* 1974; *Dyachuk,* 1976; *Blyth et al.,* 1998].

2. ASSESSMENT OF CORONA DISCHARGES INTENSITY (FREQUENCY)

There are the only assessments of corona discharges frequency in the case of colliding pairs of precipitating drops [*Shishkin,* 1964, 1971, 1974, 1983*; Stalevich et al.,* 1979a, 1979b]. If we accept that each impact of drops results in corona discharge than for precipitation rate of 10mm/h there are 10 $m^{-3}s^{-1}$ corona discharges in cloud. Results of laboratory experiments had shown that corona discharge takes place also when 2 drops approach each other. Calculations of the frequency of approaching drops had shown that for low precipitation intensity (I=0.5 mm/h) there are 10^{30} times more approaches of small drops (r=0.2mm) in comparison with large ones (r=4-5 mm). It is not yet clear now what minimum sizes and distances between approaching particles ignite corona and hence intensity of discharges is unknown in case of approaching drops.

3. DROPS AND CRYSTALS CHARGING DUE TO CORONA

Corona discharge results in intensive air ionization, so charging of drops and crystals can take place. Laboratory experiments had shown that liquid drops obtain greater charge in similar conditions in comparison with crystals [*Shishkin et al.,* 1973; *Pershina et al.,*1976,1977]. Significant volume charge (up to several C/km^3) was measured. Prevailing negative fog charging was registered. Theoretical investigations of charge increase on drops due to presence of corona discharges between falling precipitating drops had shown that drops can get charge nearly

100-200e during 30 s . Intensity of ionization is equal to 10^4 $cm^{-3}s^{-1}$ for precipitation rate I=10mm/h. This intensity of ionization is 4 orders of magnitude greater than for usual conditions [*Shishkin,* 1971]. *Griffiths* [1976] had shown that crystals can get rather big charges (0.1-0.5 nC) as a result of corona discharge.

4. ELECTRIC CURRENT OF CORONA DISCHARGE

Crab et al. [1974] had shown that corona discharge between 2 large drops results in 4-10 electrical pulses. Every pulse has charge nearly 10^{-10} C. Pulse duration decrease and amplitude increase if distance between discharging particles is decreased [*Chauzy et al.,* 1989]. Measurements of corona discharge current from different sizes crystals had shown that it is equal to 10^{-7}A [*Griffiths et al.,* 1974]. For temperature greater than –18^{o}C there is increase in discharge current which is very similar to current from drops. It is the result of formation quasi liquid layer on the surface of a crystal [*Coquillat et al.,* 1995]. Typical pulse duration is 20 ns, transferred charge – 6600 pC [*Chauzy et al.,* 1989]. Pulse duration from melting hail is equal to 10^{-2}s and current is equal to 10^{-6} A [*Dyachuk et al.,*1979].

5. ION CONCENTRATION IN CLOUDS AS A RESULT OF CORONA DISCHARGES

Theoretical analysis of experiments of *Sartor et al.,* [1967] was carried out by *Shishkin* [1971]. There took place corona discharge between pairs of charged drops (0.21 esu.) in horizontal electrical field in experiments of Sartor. Potential of such drop was equal to $1.6*10^{12}$ eV. One knows that for most atmospheric gases ionization potential is within the limits11-20 eV. If all the energy of approaching drops is spend into ionization, than there can appear 10^{11} pairs of ions in neighborhood to corona discharge. Results of consideration of some model cloud had shown that there are 10 $cm^{-3}s^{-1}$ corona discharges in it, so ionization velocity is equal to $10^7cm^{-3}s^{-1}$. Assessments of ionization rate for crystal discharges [*Griffiths et al.,* 1974b] had shown that number of ions could be 10-100 times greater in cloud in comparison with uncloud air and be equal consequently (10-100)*1000 cm^{-3}.

6. IGNITION OF STREAMERS AND LIGHTNING BY CORONA DISCHARGES

When positively charged precipitation will reach negatively charged drops than due to local increase of electrical field strength appears possibility for corona discharges and they can ignite streamer. There will be favorable conditions for it distribution into the region of negatively charged drops and it can results in lightning [*Griffiths et al.,* 1976a]. It is important that electrical field strength which ignite streamer differ from that which is needed for it spreading in cloud [*Griffiths et al.,* 1974a]. Positive streamers have advantage in comparison with negative ones. Electrical field strength have to be greater than 400-500 kV/m [*Crabb et al.,* 1974]. If electrical field strength is greater than threshold number one can observe intensification of the streamer due to increase of positive charge in its head and negative at the tail [*Griffiths et al.,* 1976]. Detailed theoretical speculations of *Coquillat et al.* [1994] had shown that to ignite streamer there is need for drops r=1 mm, q=280 pC to exist in electrical field strength of 500 kV/m at height 6 km, or q=310 pC at electrical field strength 400 kV/m. Though charges and electrical fields are rather big there are indications that such conditions take place in Cb [*Marshall et al.,* 1982]. In accordance with *Dawson et al.* [1965] radius of streamer head is nearly 30 mkm, and charge of streamer head is equal to 10^8e.

7. LOSSES OF MASS BY DROPS AND WATER-ICE TRANSITIONS AS A RESULT OF CORONA DISCHARGES

As it was mentioned above, there is ejection of small drops from big one during corona discharge. Mass loss increases for larger drops and greater electrical field strength [*Macky* 1931; *Latham* 1965]. Mass losses are significantly greater during ejection of positive drops in comparison with negatives and can obtain 25-60% [*Abbas* et al., 1967; *Matthews* 1967]. So the process can lead to negative charging of large drops. Significant mass losses were observed at rather large electrical fields 700-900 kV/m. Taking into the account the fact that in accordance with the modern knowledge's electrical field strength do not exceed 400 kV/m, one can expect that this process can take place only for drops located not too far from lightning and streamers, where electrical field strength can vary significantly [*Afanasev et al.,* 1996].

Supercooled drops freezing can take place in the vicinity of corona discharge. Laboratory experiments had shown that drops with radius 0.5-0.7 mm located near corona discharge can freeze at temperature –3 - -5 ^{o}C [*Bashkirova et al.,* 1979; *Dovgaljuk et al.,* 1999; *Stepanenko et al.,* 2002]. It is important to mention that alternative electric field forming corona discharge lead to increase of freezing temperature in comparison with constant electrical field [*Dovgaljuk et al.,* 1999; *Stepanenko et al.,* 2002].

8. ELECTROMAGNETIC EMISSION

One knows that electrical discharges results in electromagnetic emission in wide range. Corona dischargers as one type of dischargers also results in some emission of electromagnetic energy [*Chauzy et al.,* 1989]. Experiments had shown that emitted power depends on the distance between discharging particles. Emitted energy was in the range of radio frequencies 10^7-10^9 H, pulse duration – 2-3 ns.

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