LABORATORY EXPERIMENTS ON THE EFFECT OF TRACE CHEMICALS ON CHARGE TRANSFER DURING ICE CRYSTAL- HAIL COLLISION

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INTRODUCTION

One of the major mechanism which tries to explain the thunderstorm electrification is the charge transfer during ice crystal graupel collision also known as non inductive charging mechanism. Several experiments conducted world wide show that the sign and magnitude of charge transfer depends on the size and velocity of the impacting ice crystals, the liquid water content, temperature, rime accretion rate (RAR) and relative humidity at which the ice crystals grow and the surface properties of the interacting ice crystals and graupel (Reynolds et al, 1957; Takahashi, 1978; Jayaratne et al, 1983; Keith and Saunders, 1990; Saunders et al, 1991; Pereyra et al, 2000; Berdeklis and List.2001)

The present laboratory study involves the charge transfer experiments with trace amount of chemicals involving small ice crystals at low values of RAR.

EXPERIMENTS

Laboratory experiments were carried out to investigate the charge transfer during the collisions between ice crystals and graupel at an impact velocity of 2.2 m/s using pure water (Milli-Q 18.2 Mohm - cm) and trace amount of chemicals at low RAR and crystal size below 50 µm diameter. Experiments were conducted inside the cylindrical steel chamber (238 litres) kept inside the walk - in cold room (8X4X8 ft) which can reach a temperature of - 30 °C. The cloud temperature varied from - 6 to - 25 °C. A charge detecting amplifier is connected to the target made of platinum plate.

Fig 1: Experimental setup.

Experiments were carried out with pure water alone and also with solutions of ammonium sulphate, ammonium chloride and sodium chloride at 5 X 10^{-5} N. A cloud of supercooled droplets and vapour are formed inside the experimental cloud chamber by heating the solution and ice crystal formation in the cloud is initiated by momentarily introducing a rod dipped in liquid nitrogen. The cloud of supercooled droplets and ice crystals are drawn past the graupel grown on the platinum target through a side tube attached to the experimental chamber. The charge transferred to the graupel is measured. Formvar coated slides having the same size of target are kept inside another tube below the charge transfer tube, on which ice crystals and droplets are collected at the same impact velocity. These slides are used for microphysical analysis and computation of RAR.

RESULTS AND CONCLUSIONS

Experiments with pure water (Milli-Q) at different temperature regions show the dependence of charge transfer sign on temperature and RAR.

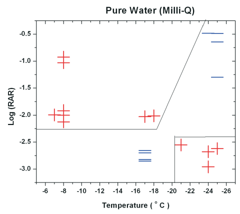

Fig 2: The positive and negative graupel charging regions as a function of temperature and RAR for pure water.

The present experimental result with solution of Milli-Q water and ammonium sulphate (5X10^{-5} N) show increase in positive graupel charging at all temperature region with increase in RAR. The experimental results with solution of Milli-Q water and ammonium chloride (5X10^{-5} N) also show increase in positive graupel charging at higher RAR at all temperature range. Experimental results show the magnitude of the charge per crystal transferred to the crystal decreases positively and changing towards the negative with increasing RAR for solution of Milli-Q water and Sodium Chloride (5X10^{-5} N).

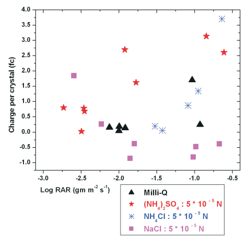

Fig 3: Ice crystals interacting with graupel made from pure water and different chemical solutions at 5 X 10^{-5} N at temperature region ranging from -6 to -10 °C.

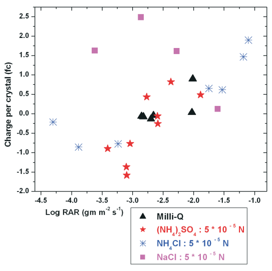

Fig 4: Ice crystals interacting with graupel made from pure water and different chemical solutions at 5 X 10^{-5} N at temperature region ranging from -16 to -19 °C.

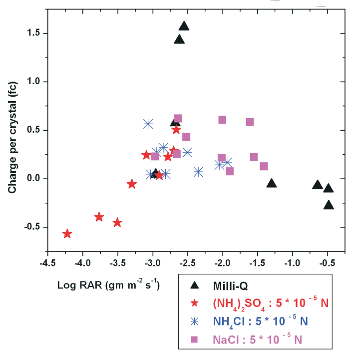

Fig 5: Ice crystals interacting with graupel made from pure water and different chemical solutions at 5 X 10^{-5} N at temperature region ranging from -21 to -25 °C.

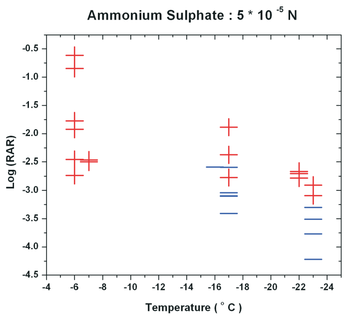

Fig 6: The positive and negative graupel charging as a function of temperature and RAR for ammonium sulphate solution of 5 X 10^{-5} N.

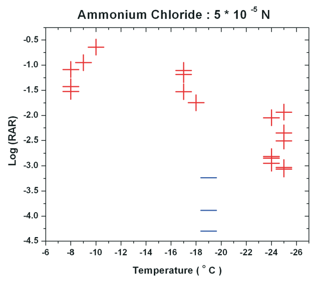

Fig 7: The positive and negative graupel charging as a function of temperature and RAR for ammonium chloride solution of 5 X 10^{-5} N.

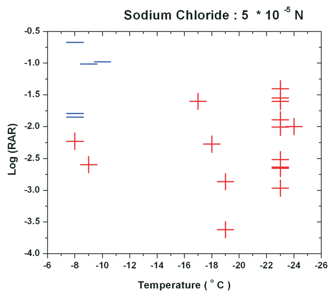

Fig 8: The positive and negative graupel charging as a function of temperature and RAR for sodium chloride solution of 5 X 10^{-5} N.

Laboratory measurements of sign and magnitude of charge transfer during the ice crystals graupel collision with trace amount of ionic compounds with crystal sizes below 50µm at different temperature regions are in agreement with that of previous studies (Jayaratne, 1981 and Jayaratne et al 1983) and also obeys the negative and positive charging zones of Saunders et al (1991) for pure water toward the higher values of RAR. The positive and negative graupel charging regions differs from that of pure water charging regions depending upon the ionic compounds used. This change in sign or polarity of the charging regions with trace amount of ionic compounds may affect the polarity of charge distribution in the thunderstorms. This may result in positive cloud to ground lightning and increase in number of sprites.

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