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# Atmospheric Electric Field Strength and Ice Crystal Charge Associated with Precipitation in Northern Canada

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**Abstract**

Atmospheric electric field and electric charges on precipitation particles were measured at Inuvik in winter of 1977.

In a light intensity of precipitation of the dendritic crystal type, charges on the individual crystals were small usually below 1 fC. Although charges of needle type crystals were fortunately measured, they were also very small below 1 fC. The effect of drifting snow was found to introduce a negative going spike type of an impulse onto the stable field value. In a high falling density of dendritic crystals, the effect of negative ice crystals were marked to augment a positive atmospheric electric field. In spite of such a time of year in those area, the accretion of supercooled droplets onto the ice crystal was found. Rimed sector plates or columns as well as graupel were positively charged.

## 1. Introduction

The electric charges associated with snow crystals and the effect they have on the earth's atmospheric electric field were studied by Magono and Orikasa (1966) and Owolabi (1970). They showed that there seemed to be an inverse relationship between the signs of the electric charge on precipitation particles and the direction of the atmospheric electric field. Most of such observations were carried out during winter at middle latitudes. Only rarely were such observations carried out in high latitudes. Kikuchi (1973) is one example. He showed in Antarctica that, in general, crystals of the warm type (dendrites, sectors and plates) exhibited negative charges, while crystals of the cold type (columns, sideplanes and combinations of bullets) exhibited positive charges.

In the winter of 1977, the authors conducted a research expedition to Inuvik to study the detailed structure of snow crystals in the cold regions of Canada and also to try and measure the atmospheric electric field and crystal charges under a project of "The Scientific Research on Snow Crystals of Cold Temperature Type in Canada".

## 2. Observations

The observation site was the Inuvik Research Laboratory in Inuvik (68°22'N, 133°42'W), Northwest Territories, Canada. The earth's atmospheric electric field was measured with a portable radioactive probe, specially designed to operate in cold weather. Snow crystal charge was measured by allowing the particles to deposit into a shielded brass collection cup, 5 cm in diameter. Both of these instruments were operated continuously from January 15 to February 6, 1977. During periods of snow fall, detailed information of crystal sizes and shapes was obtained with facilities including a polarization microscope and the Formvar replication technique.

Fig. 1 shows a diagram of the radioactive probe used. The input resistance of $10^{13}$ ohms and an electrometer operational amplifier are contained within a brass tube, 2 cm in diameter. The brass tube is pressurized with nitrogen

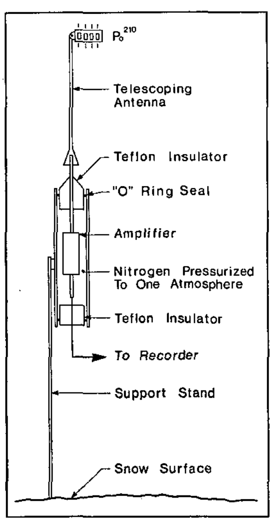


Fig. 1

Fig. 1 Schematic diagram of the radiation probe.

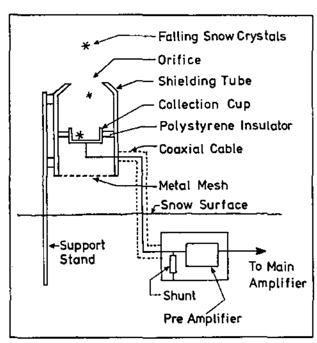


Fig. 2

Fig. 2 Schematic diagram of the charge collection device.

gas of one atmosphere. The radioactive substance is Polonium 210 of 500 microcurries. The source is mounted on a telescoping antenna unit. This allows the source to be maintained at a constant height of about one meter from the snow surface. Hence, the atmospheric electric fields were computed from the potentials divided by the source height from the surface.

Fig. 2 shows a schematic diagram of the charge collection cup. Snow crystals enter the cup orifice of 5 cm in diameter and transfer their charges to a specially designed pre-amplifier and then to a main amplifier. Charges on crystals in the range of 0.1 to 10 fC per crystal can be easily measured. An electric shielding tube is designed to protect the cup from charging due to snow crystals hitting the side of the unit and from atmospheric electric field disturbances. Each charged snow crystal transmits a discrete electric impulse to the pre-amplifier.

The electric field and charge units were operated continuously during the observation period. Both signals were recorded on the same chart recording paper of a dual channel recorder. Shapes of snow crystals were determined by direct collection of the crystals at a nearby location, either with a one percent solution of Formvar in ethylene dichloride and by direct observation of the crystals with a polarization microscope.

## 3. Results

The fair weather atmospheric electric field within the town was positive in the range of 90 to 120 V/m. Natural snow crystals carried electric charges. Consequently, a snow fall which possessed atmospheric electric space charges caused the strength of the atmospheric electric field to change. Several examples of this phenomenon are shown as follows.

Fig. 3 illustrates an effect of the precipitation of the sector plate type of crystals falling with light intensity. Charges on individual crystals were small, usually below 1 fC. Between 14:30 and 14:40 LST, a group of crystals arrived with mixed positive and negative charges and the net effect was to slightly depress the atmospheric electric field. The surface air temperature during this observation was −22°C.

Needle type snow crystals were observed on January 25th, 1977. The needle type of snow crystal is very rare during this time of year. Electric charge of the needle type crystals was very small as shown in Fig. 4. Consequently, there was little effect upon the electric field. The surface air temperature during this period was −12°C.

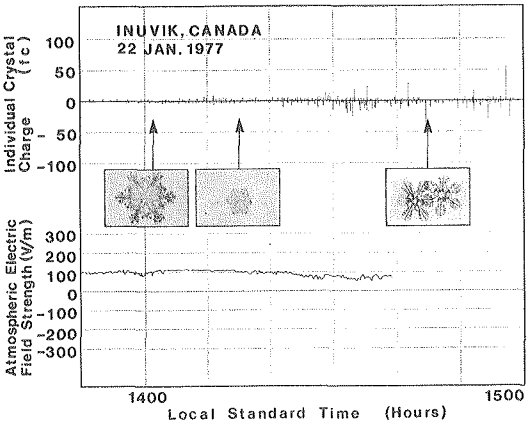


Fig. 3 Atmospheic electric field and charge variation with a light dendritic crystal fall.

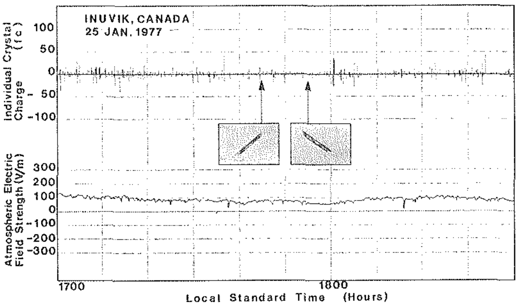


Fig. 4 Atmospheric electric field and charge variation with a snowfall of needle type.

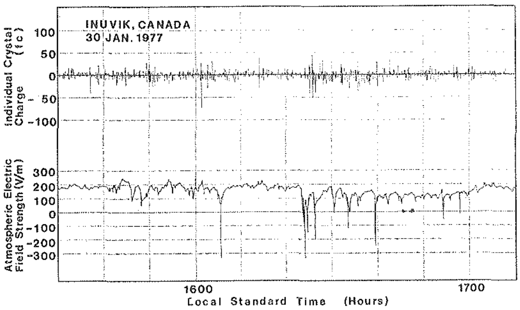


Fig. 5 Snow drifting effect.

Fig. 5 shows the effect of drifting snow on the electric field. The effect of drifting snow introduced a negative spike onto the electric field. Snow crystals were blowing along the snow surface with velocities up to 10 m/sec. They were fragmented in the shape and locally influenced the probe as wind gusts collected the crystals into groups and transported them past the probe. The spiking phenomenon as seen in Fig. 5 was directly associated with the local effect of wind turbulence. However, the average atmospheric electric field was not significantly altered from the fair weather value.

An effect of the dendritic crystals of high falling density on the electric field is shown in Fig. 6. The natural charge on the crystals was predominantly negative with magnitudes as high as several tens of fC. Both positive and negative charges were observed on the crystals at this time, but the net charge was predominantly negative. The surface air temperature during this observation was –22°C with light winds. Dendritic crystals in these observations are transporting a net negative charge to the earth's surface and strengthening the normal fair weather field to values approximately three times the fair weather value. Therefore, an inverse relationship between negative charged dendritic crystals and positive electric field as reported by many workers in middle latitudes was recognized in high latitude.

The electrical influence of the accretion of supercooled droplets onto the ice crystals is shown in Fig. 7. The time intervals where droplets and ice crystals occurred simultaneously is shown in the figure. Crystals of the columnar and stellar types were heavily rimed with droplets 10 to 30 microns in diameter. At about 20:30 LST the droplets began to appear. The atmospheric electric field went quickly to negative and remained there as long as the riming process was being reported. At 23:00 LST the riming process ceased and the electric field reversed to positive. During the period when supercooled drops were reported, lightly rimed crystals and heavily rimed particles (graupel) were observed. In isolated cases, mixtures of both frozen and unfrozen droplets were observed. The individually observed charges were both positive and negative.

The radiosonde observation at the upper air station at 17:00 LST on January 25 showed that the air temperature was –5.7°C around the 850 mb level as compared with the surface air temperature of –14°C. This confirms the presence of warm air in the upper levels of the atmosphere.

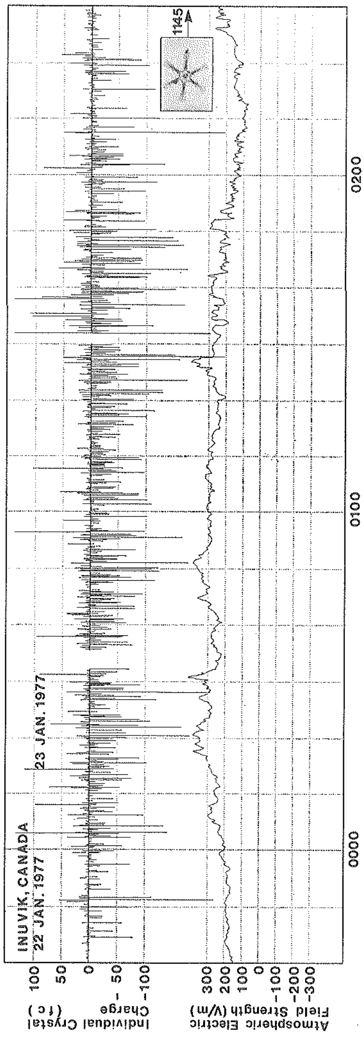


Fig. 6 The inverse relation effect.

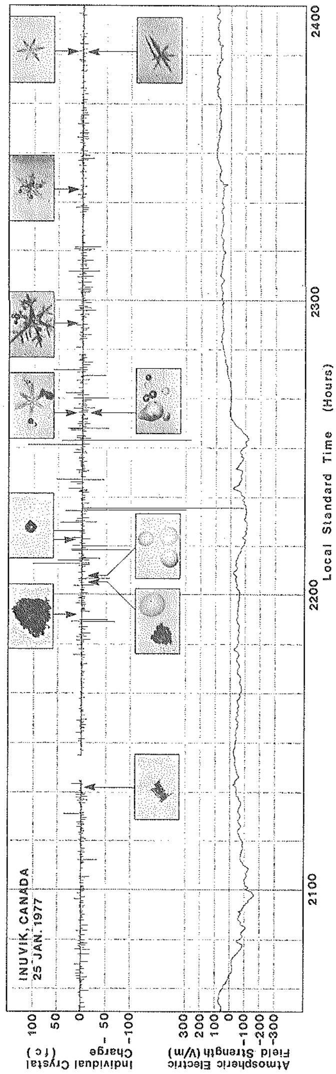


Fig. 7 Crystal riming effect.

## 4. Consideration

Strong static friction effects of snow crystals acting with each other and with the snow surface would produce negative spike effects on the electric field. Kikuchi (1975) reported that the negative spikes in the atmospheric electric field were associated with the drifting snow in Antarctica. According to this observation, crystal shapes during blowing snow were of the bullet and column types and combinations of different types of bullets. There was also a great abundance of fragmented and crystal clusters in those cases.

The effect of negative (positive) ice crystals augmenting the positive (negative) atmospheric electric field is known as the inverse relation. According to Magono and Orikasa (1966) and Owolabi (1970), the inverse relation may be also considered in the following way. The inverse relation as revealed in the present observations implies that some crystals acquire negative charge from atmospheric ions, either by a diffusion or by a scavenging process. The crystals then precipitate the resulting negative charge to the ground. An excess of positive charges is then left in the air aloft, which augments the atmospheric electric field.

During the time intervals when there is a large flux of highly charged ice crystals, the electric field values are rapidly increased. This indicates that transport of the negative charge toward the earth is greatly increased.

The accretion of supercooled droplets onto the ice crystals results in a direction change of the atmospheric electric field. Net charges on the falling particles are positive in this case. The laboratory experiments by Shewchuk and Iribarne (1974) confirmed for low impact collision speed (1 m/s) of ice particles with supercooled droplets, that ice particles received a predominantly positive charge. Magono and Takahashi (1963) also showed that under the air temperature above $-10°C$ and at low riming rates, ice particles carried positive charges. The charging is somewhat dependent on the composition of liquid droplets, but in most cases it is positive. Rimed sector plates or columns as well as graupel are predominantly positively charged. The effect of space charges of falling, positively charged precipitation is to reverse the atmospheric electric field to normal (fair weather) values. The present observations definitely support the presence of supercooled drops which change the sign of the atmospheric electric field. As the effect of this riming collection decreases, and the precipitation types return to unrimed crystals, the atmospheric electric field returns to its fair weather value.

The atmospheric electric field observed during precipitation was weaker than that which had been observed in comparable intensities at middle latitudes. This may be due to the fact that in all cases the precipitation was observed to come from cold, non-convective clouds. In middle latitudes, the mixing of liquid and solid phases of particles is observed to create larger charging effects than the solid or liquid phase individually. At Inuvik, Canada, the dominance of the solid, cold phase of clouds seems to create weaker charging effects during precipitation.

## 5. Conclusion

It was apparent from the observations of needle and sector plate crystals that these shapes had little electric charge retention. While very large amounts of charges were measured on dendritic crystals.

Snow drifting effects were observed in the shapes of negative spikes of atmospheric electric field records. They may be cause by strong static friction between the drifting snow particles.

When unfrozen and frozen droplets together with rimed crystals were observed, the atmospheric electric field was changed to negative values. Also in those cases, the inverse relation was applicable.

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