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Direct observations of aerosols attached to falling snow crystals

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ABSTRACT

Aerosols attached to falling snow crystals were directly observed utilizing optical and electron microscopes in Sapporo in March 1973 and 1974. It was determined that the aerosols were picked up by snow crystals during their fall under the cloud base.

Because the slope of size distribution of aerosols attached to snow crystals was nearly the same as Junge distribution in the range 0.1 to 5 μ, it was considered that falling snow crystals captured aerosols with a collection efficiency almost similar to neighbouring size ranges against the general theory of collection efficiency.

The collection efficiency was also calculated by the use of surface density of aerosols attached to the surface of snow crystals. The results of calculations showed that the apparent collection efficiency was as high as near unity.

With regard to the collection phenomena of aerosols by falling snow crystals, all possible mechanisms considered were checked to define the high collection efficiency, however it was hopeless to explain the high collection efficiency by the use of the mechanisms. This suggests that there are some unknown mechanisms remaining in the natural washout of aerosols by falling snow crystals.

1. Introduction

It is popularly well known that the air becomes considerably more clear after a snowfall and this clearance of air decidedly relates to the snowfall, however, its physical mechanism is not yet understood.

Polluted air is distributed in a lower layer over the city; it exists under the cloud base. Therefore it is considered that the clearance is related mainly to the washout effect of falling snow crystals, not the rainout phenomena. Magono et al. (1974) have made simultaneous measurements of the falling rate of snow crystals and the decreasing rate of aerosol concentration in Sapporo, and estimated that the collection efficiency of aerosols by the falling snow crystals was as large as 0.2 to 0.5. These values were much greater than generally expected from a theoretical point of view.

It is, however, difficult to understand that the aerosols were captured by falling snow crystals, because aerosols of micron or submicron size are too small to be collected by dynamic impaction by the falling snow crystals, and they are too large to be transported to the surface of snow crystals by diffusion phenomena, as calculated by Greenfield (1957). It is therefore important to resolve the problem about the discrepancy between the observation and the theory, not only from the viewpoint of air pollution, but from the cloud–physical point of view.

The authors undertook experiments to verify directly that aerosols are able to be collected by falling snow crystals, then made observations of aerosols which were attached to the falling snow crystals, utilizing an optical microscope in 1973 and an electron microscope in 1974 in Sapporo. The results of the observations will be described later.

2. Measuring methods

Optical micrographs were used to measure the

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size distribution of aerosols of micron size attached to falling snow crystals, by the use of evaporated traces of the snow crystals. Before measurement, it was anticipated that aerosols in the traces would be moved towards the centre of a snow crystal, then coagulate with each other in the evaporation process, as reported by Nakaya et al. (1958). Therefore several methods were tried to avoid the movement and the coagulation phenomena in the process. Finally it was found that extremely gradual sublimation at a temperature of about −20 °C was best in order to minimize these phenomena.

Electron micrographs were used to observe aerosols of submicron size. In the case of electron microscopic observation, however, a special technique was required in the sampling process of falling snow crystals. If a snow crystal was replicated by the usual solution of polyvinyl formvar, the beam of electrons cannot penetrate the specimen, while if the solution is so dilute and thin as permeable, it cannot cover the upper surface of the replicated snow crystal. Finally the authors adopted the following technique in the sampling process, as shown schematically in Fig. 1.

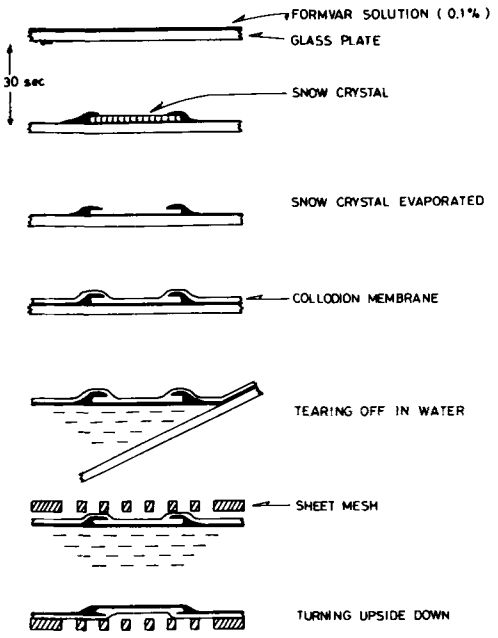

Fig. 1. Sampling process of aerosols attached to a snow crystal for electron microscopic observation.

A clean glass plate is coated by polyvinyl formvar solution of 0.1%. 30 s after coating, a snow crystal is sampled on the plate, but the dilute solution cannot cover the upper surface of the crystal. After the snow crystal is evaporated at a temperature below freezing, the area is covered by a collodion membrane. Thus aerosols attached to the snow crystal are sandwiched between these two membranes. This double membrane is then torn off the glass plate with the help of clean water and is put on a mesh sheet which is used for normal electron microscopic observations.

According to the result of a blank test for background dust particles, it appeared that aerosols were somewhat spread out from the periphery of the branches of a snow crystal, however no dust particles were recognized in the area which was far apart from the branches. The detailed description of the sampling technique is found in Magono et al. (1975).

3. Results

3.1. *Optical microscope observations*

Early in the morning of March 10, 1973, snow crystals of dendritic plane type occurred, and the grade of riming was relatively small, as illustrated in Photo. 1, Pl. I. The sublimated trace of the snow crystal is given in the same magnification factor in Photo. 2. The numerous spots in the photograph are aerosols which were attached to the snow crystal. It may be seen that aerosols were moved from the end of branches to the axis of the main branch, but no significant coagulation occurred during the sublimation process.

Representative portions in Photo. 2 were further photographed with a high magnification, as illustrated in Photo. 3. It may be seen that there are black spots and half-transparent spots in Photo. 3. The former may be made of smoke particles because they appear to be carbon black particles. The latter may be related to oil droplets, because they appear to be liquid droplets.

By counting aerosols in several such high-magnification photographs, a size distribution was obtained, as shown in Fig. 2, in which the diameter of aerosols is indicated in the horizontal axis and the number of aerosols counted is indicated in the vertical axis in an interval of 0.2 μ in diameter. The shaded and unshaded areas in the histogram show

Plate I. Aerosols attached to a snow crystal of plane dendritic type.

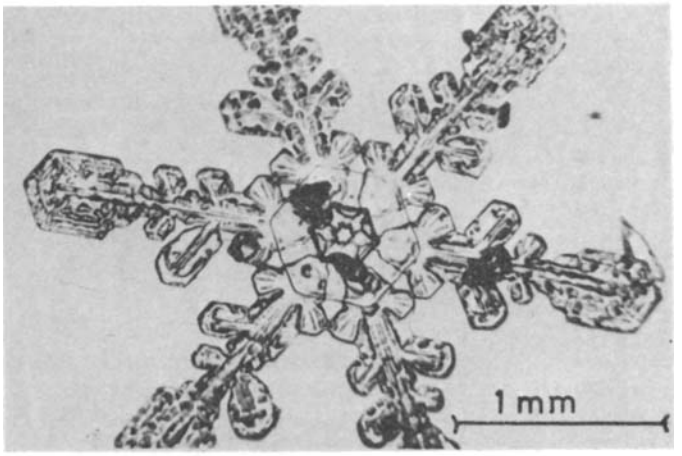

Photo. 1. Optical micrograph.

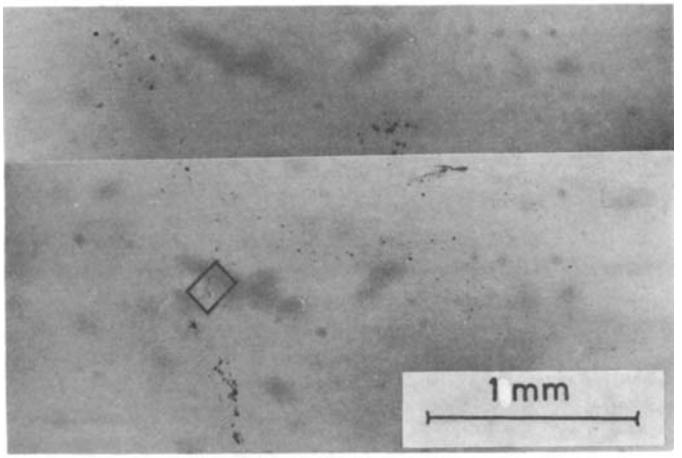

Photo. 2. Sublimated trace of the snow crystal of the same size as Photo. 1.

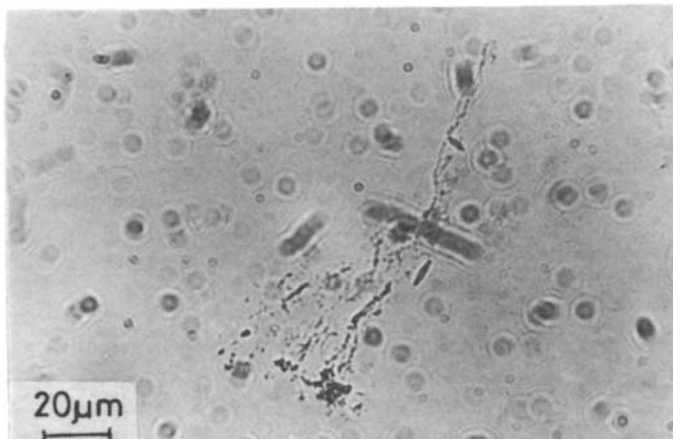

Photo. 3. Magnified photograph of a portion enclosed by a tetragon in Photo. 2.

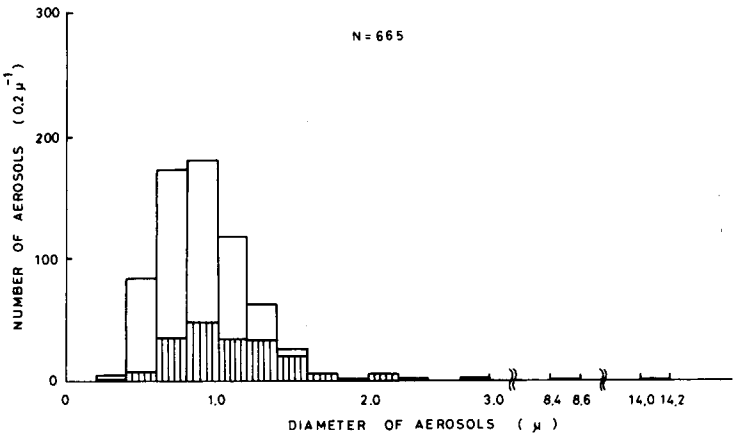

Fig. 2. Size distribution of aerosols attached to a snow crystal of plane dendritic type (optical micrograph).

the number of black spots and half-transparent spots, respectively. The N in the figure shows the total number of spots counted. It is noted that the number of aerosols counted are fairly great in spite of the small portion of the snow crystal, although the snow crystal was scarcely rimed and the number of aerosols smaller than 0.4 μ in diameter is not exact. Considering the area density of aerosols counted, it is estimated that about 4000 aerosols were attached to the snow crystal.

The mode of size distribution is usual, although the distribution is scattered in a range up to 14 μ diameter. This scattering is caused by the insufficient number of aerosols counted in this range. In the case of larger aerosols of micron size, their diameter means the average of major and minor diameters. It may also be seen that the size of black spots is distributed in the larger range, compared with half-transparent spots.

In the snowfall on the morning of March 14, snow crystals were rimed, as illustrated in Photo. 4, Pl. II. The illustrated snow crystal of needle type is rimed as densely as a graupel; in other words it is mostly composed of frozen cloud droplets. The sublimated trace of the needle crystal is shown in Photo. 5 in the same size, and a magnified portion enclosed by a tetragon is given in Photo. 6. Counting aerosols in such photographs, size distribution was obtained as seen in Fig. 3. There is no significant difference in the mode of size distribution from Fig. 2, however it is noted that the number of aerosols counted in the same area was about two times greater than in the previous unrimed plane snow crystal. This difference may be due to the high grade of riming, more exactly due to the addition of condensation nuclei of frozen cloud droplets.

Besides these two snow crystals, aerosols attached to three snow crystals of plane type were measured using the same method. One was unrimed, the others rimed. The average size distribution of aerosols in all the snow crystals measured is shown in Fig. 4. The mode of distribution is similar to that of cloud droplets, although their absolute sizes are one order smaller than cloud droplets. It appears that the maximum is near 1.2 μ in diameter, however this maximum is the only one apparent, because aerosols smaller than 1 μ are apt to be missed in counting due to the resolution power of the microscope used. Nevertheless it can be concluded that the number of attached aerosols increases smoothly as their size decreases down to 1 μ.

3.2. *Electron microscope observations*

Falling snow crystals were sampled to measure the size distribution of aerosols of submicron size attached to the snow crystals, utilizing an electron microscope in Sapporo in March and April 1974. In order to eliminate the condensation nuclei of rimed droplets, and to make it easy for the penetration of the electron beam, unrimed snow crystals of plane type only were sampled. In addition, due to the difficulty in the replication and fixing process of aerosols, we succeeded in sampling in only a few cases.

Plate II. Aerosols attached to a rimed snow crystal of needle type.

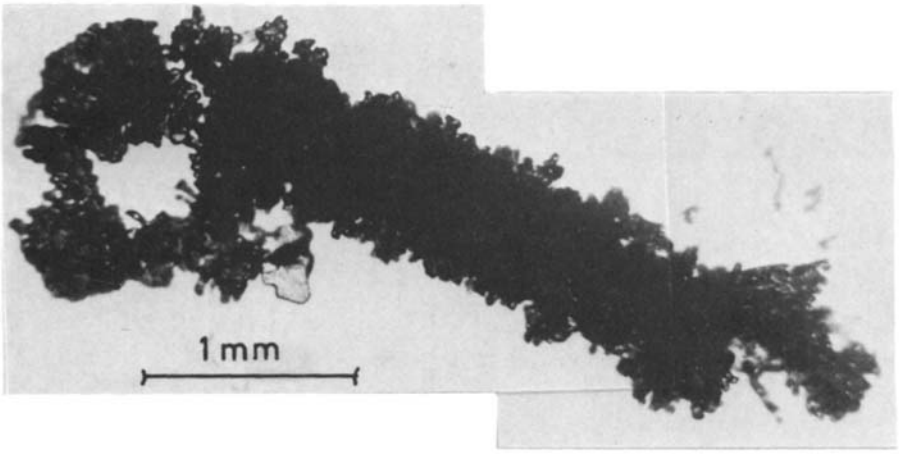

Photo. 4. Optical micrograph.

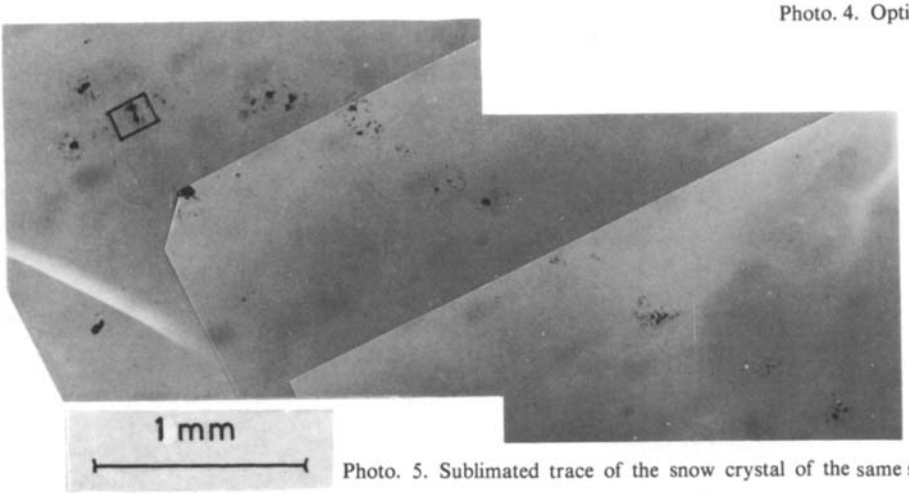

Photo. 5. Sublimated trace of the snow crystal of the same size as Photo. 4.

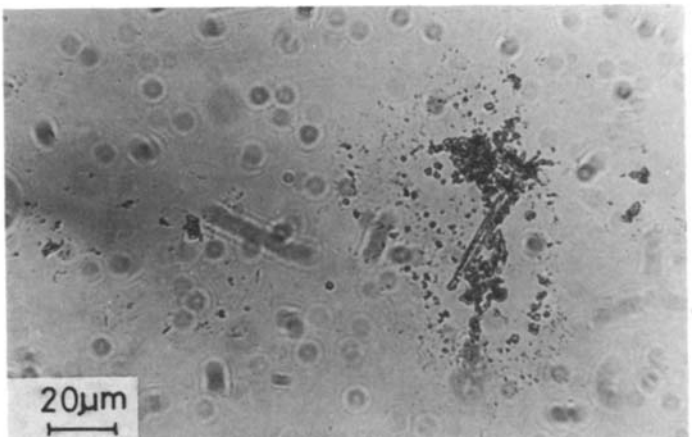

Photo. 6. Magnified photograph of a portion enclosed by a tetragon in Photo. 5.

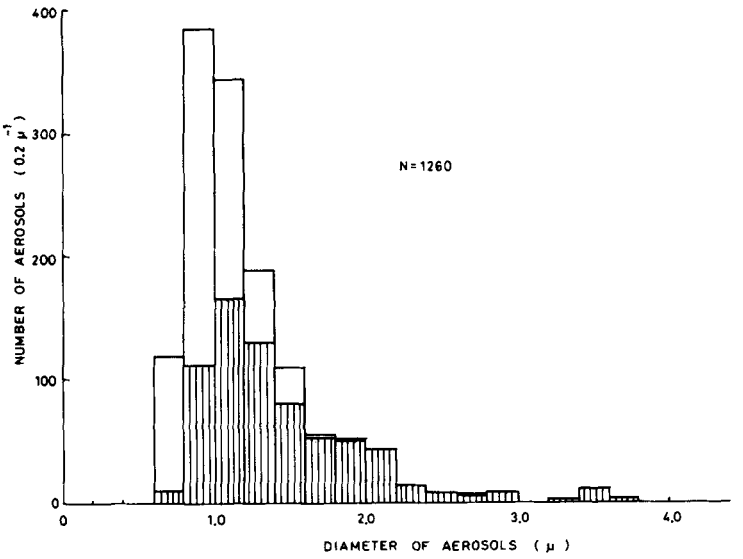

Fig. 3. Size distribution of aerosols attached to a rimed snow crystal of needle type (optical micrograph).

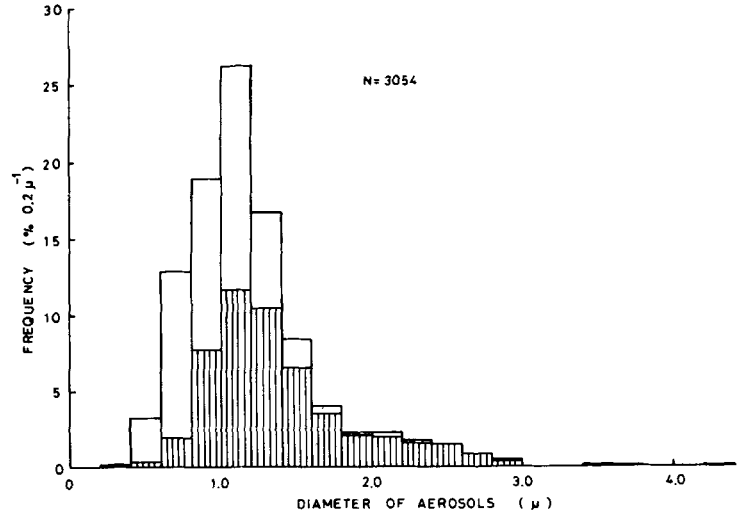

Fig. 4. Total size distribution of aerosols counted from five snow crystals of various types (optical micrograph).

One of the replicas of a snow crystal of plane dendritic type is shown in Photo. 7, Pl. III. Hereinafter this snow crystal will be called "Crystal *A*". A portion of a branch, indicated by arrow *a* in the photograph, was magnified by an electron micrograph, as shown in Photo. 8. Another arrow *a'* shows the portion for the blank test where no dust particles were recognized.

The size distribution of aerosols counted from Photo. 8 and a similar photograph in crystal *A* is shown in percentage in an interval of 0.05 μ in Fig. 5. The resolution power of the electron microscope used was 0.025 μ. The total number of aerosols counted, *N*, and the area of surface used for the measurement, *S*, are given in the upper portion of the figure. It may be seen that the frequency of

Plate III. Submicron aerosols attached to a non-rimed snow crystal of plane type.

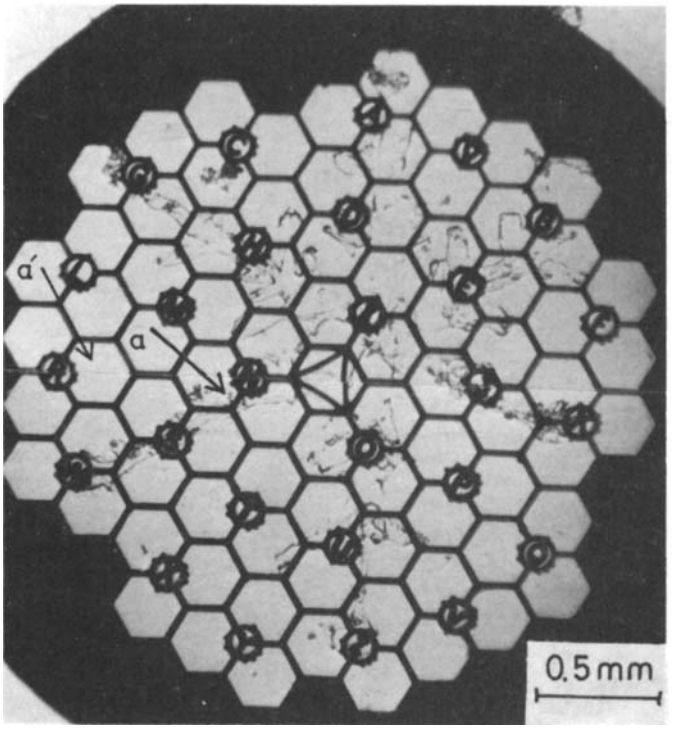

Photo. 7. Optical micrograph.

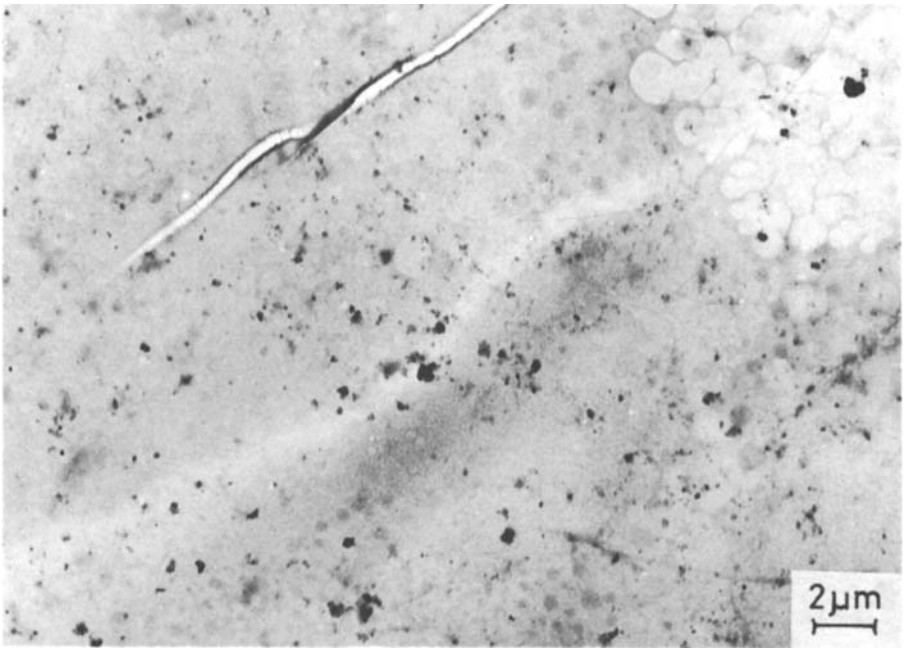

Photo. 8. Electron micrograph of a portion indicated by arrow *a* in Photo. 7.

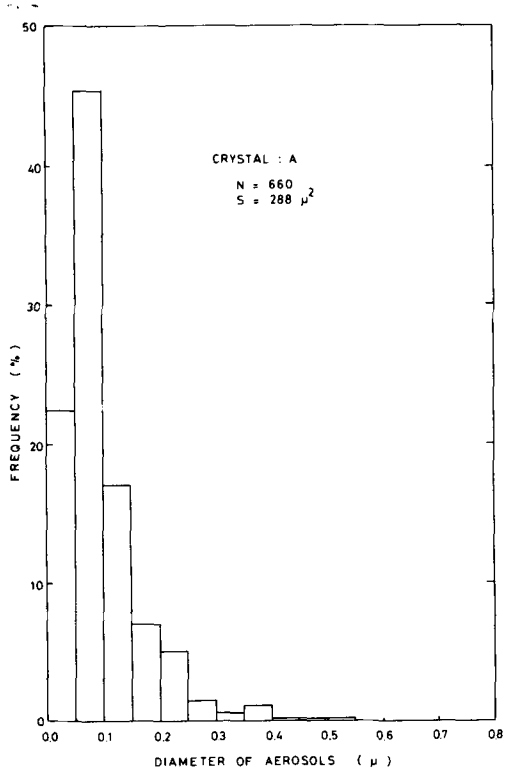

Fig. 5. Size distribution of aerosols attached to snow crystals *A* of dendritic plane type (electron micrograph).

aerosols increases smoothly as their size decreases down to 0.1 μ in diameter. The decrease in range smaller than 0.05 μ is the only one apparent, because small aerosols near the resolution power of the electron microscope are apt to be missed in counting.

Similar measurements were also made for other snow crystals *B* and *C*, and almost uniform distributions as in Fig. 5 were obtained.

3.3. *Comparison with airborne aerosols*

It may be interesting to compare the size distribution of aerosols attached to falling snow crystals with that of airborne aerosols. As a typical size distribution of airborne aerosols, Junge distribution (1955) is shown by a chain line to the right of Fig. 6 where the vertical and horizontal axes show the space number concentration and the diameter of aerosols in logarithmic scale, respectively. For comparison, the present distribution obtained from crystals *A*, *B* and *C* was transformed to a surface number density, utilizing each measured area of observed snow crystals *A*, *B* and *C*, and was then plotted by black dots in logarithmic scale to the left of Fig. 6. The surface number density corresponds to the space number density in this case, because the observed aerosols attached to snow crystals were those which were swept by the snow crystals when the crystals were falling through the space below the cloud base.

In Fig. 6 black dots are distributed nearly on a straight line (solid line in the figure) and the line is parallel to Junge distribution, although they are fairly scattered in the range greater than 1 μ. This scattering was caused by the insufficient data in the range. The distribution of aerosols obtained optical-microscopically is also described by white dots. In this case the dots are also distributed on a straight line (broken line in this figure), at least in the range up to 5 μ. The difference from the electron microscopic observation may be due to the difference in the observation period.

Both in the electron micrograph and optical micrograph cases, the number of aerosols seems to be smaller than those expected by the respective straight lines in the smaller range (<0.2 μ in electron micrographs, <1.5 μ in optical micrographs). These differences originated from the transformation process from linear scale to logarithmic scale, because the number of aerosols counted in the smaller range was extremely small in the description in logarithmic scale, although the respective number was comparable with other ranges when the aerosols were counted in linear scale. If a sufficient number of aerosols were counted in extremely small and great range, the size distribution would be described by the straight line in much wider range, e.g. from 0.1 to 5 μ.

Finally it may be concluded that the slope of size distribution of aerosols attached to falling snow crystals was nearly the same as the typical distribution of airborne aerosols obtained by Junge in the range 0.1 to 5 μ in diameter. This means that there was not a particular range in which the collection of aerosols by falling snow crystals is extremely difficult. In other words, aerosols in air were captured by falling snow crystals with nearly the same collection efficiency as in other ranges.

3.4. *Surface density of aerosols attached to snow crystals*

The area of surface of snow crystals observed by the electron microscope was only a small portion compared with their whole surface, however, the

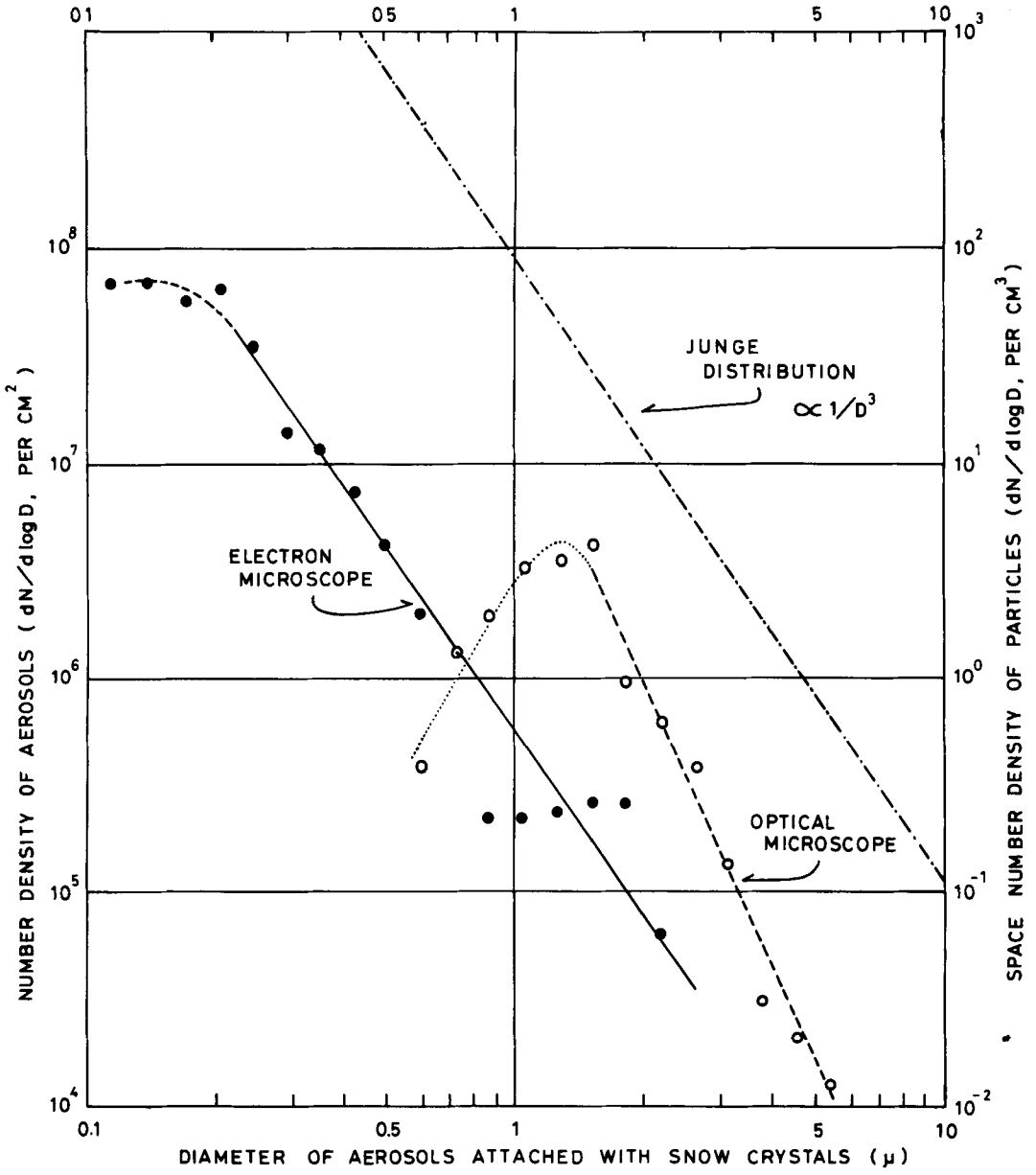

Fig. 6. Comparison of size distributions of aerosols attached to snow crystals with Junge distribution.

observed area was selected randomly as far as the photographing was possible. If the results of measurement in the limited area are uniformly applicable to other areas, it is possible to calculate the surface density of aerosols on the snow crystals, as shown in Table 1. In the table, aerosols both on the lower and the upper surfaces of snow crystals are included because it was impossible to

distinguish between these two surfaces under the electron microscope. It may be seen in the table that the surface density of aerosols was of the order of 10^8 cm^{-2}, although the value is different for each according to snow crystals.

Table 1. *Surface number density of aerosols on snow crystals*

	Snow crystals		
	A	*B*	*C*
Number of aerosols observed	660	781	1963
Area observed in μ^2	288	617	443
Surface density in $\times 10^8$ cm^{-2}	2.3	1.3	4.4
Average surface density: 2.7×10^8 cm^{-2}			

4. Discussion

4.1. *Washout*

The size distribution of aerosols obtained from the electron micrographs was mainly discussed because the scavenging mechanism of aerosols of submicron size is most interesting. It is obvious that the submicron particles attached to snow crystals were brought by the crystals, however some discussion will be required to determine whether the particles were simply scavenged by the falling snow crystals under a cloud base (washout) or were captured by the snow crystals during the growth process of the crystals (rainout).

Because the snow crystals in the electron micrographs were not rimed, as previously described, nuclei of rimed cloud droplets are not included. Accordingly, it is considered that the snow crystals were formed purely by deposition of water vapour. About the deposition growth of snow crystals, ice crystal theory states that super-cooled cloud droplets near a snow crystal rapidly vaporize, the resultant vapour then condenses on the surface of the snow crystal owing to the difference between the saturation vapour pressures of water and ice surfaces. In this case, however, it is not yet generally determined whether nuclei of vaporized cloud droplets are attached to the surface of the crystal or not. Here, based on the assumption that the cloud nuclei attach to the crystal together with the vapour molecules, an estimation of surface density of nuclei attached to the snow crystal was made as follows.

If a disc-like snow crystal with radius R and thickness h is formed from the vapour of n cloud droplets with radius r, we have the following relation between the volumes of the crystal and droplets.

$$4/3 \cdot \pi r^3 n = \pi R^2 h \qquad (1)$$

Accordingly, the surface density of cloud nuclei, $n/(\pi R^2)$, is given by $3h/(4\pi r^3)$. On the other hand, the mean diameter of cloud droplets in this season is 10–30 μ, according to observations of Magono and Lee (1973), and the thickness of unrimed snow crystals of dendritic plane type is about 10 μ, according to Nakaya (1954). For the present case, therefore, the surface density of cloud nuclei attached to snow crystals is estimated as about 2×10^6 to 3×10^4 cm^{-2}. These values are two or four orders smaller than the observed values shown in Table 1. It is therefore considered that the majority of submicron particles observed are not condensation nuclei of cloud droplets from which the snow crystals were formed, but airborne aerosols which were captured by the falling snow crystals after the formation of the crystals.

As generally expected, most city aerosols existed in the lower layer near the surface, the layer below the cloud base.

Considering the above, it was concluded that minute particles attached to snow crystals were mostly airborne aerosols which were captured by the crystals during their fall.

4.2. *Apparent collection efficiency of aerosols*

It was noted in Fig. 6 that the slope of size distribution of aerosols attached to snow crystals was almost in agreement with Junge distribution in the range 0.1–5 μ. This fact suggests that airborne aerosols were collected by the falling snow crystals in a roughly uniform collection efficiency, regardless of aerosol size, if the size distribution of the aerosols over Sapporo city had the same slope as Junge distribution.

Besides the slope of size distribution, it may be interesting to compare the surface density of aerosols on snow crystals with the space number density of aerosols suspended in air in the period of snowfall. The depth of the polluted air layer was estimated as 500 m, because the height of temperature inversion is about 500 m this season. The height of the cloud base is also about 500 m. According to the results of measurements made by

Magono et al. (1974), by the use of an aerosol counter of Gardner type, the space number density of aerosols was 8×10^3 to 2×10^4 cm^{-3} near the ground during the sampling time. And according to the result obtained by Endow and Magono (1971), the space number density at 400 m height ranged 1×10^{-3} to 1×10^4 cm^{-3} this season. Taking the average of those four values, it is estimated that the mean space number density of aerosols was roughly 1.0×10^4 cm^{-3} in the falling path of snow crystals through the polluted air layer with a depth of 500 m over Sapporo city.

The snow crystal of plane type falls keeping its plane horizontally, and the needle type falls keeping its long axis horizontally. If these snow crystals capture all the aerosols suspended in air in their falling paths of 500 m, the surface density of aerosols attached to the snow crystals with a cross section of 1 cm^2 is estimated as 1.0×10^4 cm^{-3} $\times$ 500 m, namely 5×10^8 cm^{-2}. This value is somewhat greater than the observed values, 2.7×10^8 cm^{-2}, as shown in Table 1, however, they are in the same order. This means that the collection efficiency of aerosols by falling snow crystals is about 0.2–0.9, although these values are only apparent. It is noted that these values also agree, in order, with those which were obtained by a different method by Magono et al. (1974). It is noted that these values are much greater than expected from the usual aerodynamic consideration (Ranz and Wong, 1952).

The Gardner type aerosol counter counts all aerosols greater than 0.002 μ. However, aerosols of diameter smaller than 0.05 μ were mostly missed in the electron microscopic observation owing to the resolution power. It is therefore deduced that the surface density of aerosols on snow crystals was fairly underestimated. Taking account of this underestimation, it is considered that falling snow crystals washed out almost all aerosols suspended in air in the falling path of the snow crystals, although the mechanism of the washout is not known.

4.3. *Attachment of aerosols by diffusion*

An analysis was made considering the diffusion phenomenon. It is determined that falling snow crystals stayed for 1000 sec in polluted air, because the height of the polluted air layer was estimated as 500 m and the fall speed of the snow crystals was 0.5 m$\cdot$s^{-1}. On the other hand, the mean value of surface density of aerosols was 2.7×10^8 cm^{-2}. Accordingly the collection rate of aerosols (collected number per unit area per unit time) by the falling snow crystals is calculated as 2.7×10^5 cm$^{-2}\cdot$s^{-1}.

In a steady diffusion field, the collection rate of aerosols of a snow crystal of spherical shape is given by $4\pi rDn/(4\pi r^2)$ (Fuchs, 1964), where r is the radius of the snow crystal and D and n indicate the diffusion coefficient and space number density of aerosols, respectively.

For homogeneous aerosols with radius of 0.1 μ, the diffusion coefficient is 6.8×10^{-6} cm$^2\cdot$s^{-1}. If $r = 1$ mm and $n = 1 \times 10^4$ cm^{-3}, then the collection rate by diffusion will be calculated as 0.68 cm$^{-2}\cdot$s^{-1}. This value is negligibly small compared with the observed value. Accordingly it is recognized that it is hopeless to explain the observed surface density of aerosols only by the use of diffusion phenomenon.

According to the results of calculations by Greenfield (1957), the effect of turbulent motion on the aerosol scavenging is similar to Brownian motion in the size range of 0.1 μ. Therefore, even if we recognize the turbulent motion, it is impossible to explain the great number of aerosols attached to snow crystals only by means of diffusion phenomena.

4.4. *Attachment of aerosols by impaction collision and Facy effect*

The collection efficiency of submicron aerosols by collision with falling snow crystals is so low that the estimation by extrapolating the calculated result of collision efficiency in cloud droplet size is impossible (Ranz and Wong, 1952). Even with the wake effect and the complex shape of snow crystals, it is difficult to explain the observed collection efficiency as high as near unity by the diffusion mechanism.

As described previously, the attachment of aerosols to falling snow crystals occurred under the cloud base. Accordingly the Facy effect (1962) due to the growth of the snow crystals is not considered.

4.5. *Effect of electrostatic force on the attachment of aerosols*

It is expected that the electrostatic force is effective on the attachment of aerosols to raindrops or snow crystals. Endoh et al. (1974) calculated the

force due to the electric charge between an ice sphere of 1 mm diameter with charge of 1×10^{-3} e.s.u. and an aerosol particle of 0.1 μ with charge of 1×10^{-8} e.s.u. According to their calculation, the image force is more effective than Coulomb force when the distance between the centres of the ice sphere and the aerosol particle is smaller than 1 mm.

The authors calculated the image force for the distance of 0.6 mm, in other words for the distance between the surface of the ice sphere and the aerosol particle, it was about 0.1 mm, in which the image force is more effective than Coulomb force. If the attractive force due to the image force is balanced with the viscosity force of air we obtain

$$Q^2 d/(2l^3) = 3\pi\eta v \, \mathrm{d} \tag{2}$$

Here Q, d, l, η and v mean the charge on the ice sphere, the diameter of aerosol particle, the distance between the ice sphere and particle, the viscosity of air and the speed at which the aerosol particle is attracted, respectively. Substituting the respective numerical values, we have

$$v = 0.13 \text{ cm} \cdot \text{s}^{-1} \tag{3}$$

If the fall speed of the ice sphere is 50 cm · s^{-1}, the effective time in which the image force is effective is estimated as only 2/500 s. Accordingly it is estimated that the aerosol particle is attracted only by 0.5 μ toward the surface of ice sphere under the effect of the image force. This means that the electrostatic force has no practical effect on changing the trajectory of aerosols, in other words, no effect on increasing the collection efficiency, although the force has an effect on increasing the coagulation efficiency by capturing completely aerosol particles which approach very closely.

Kerker and Hampl (1974) measured the collection efficiency of silver chloride particles of submicron size by a water drop of millimeter size. Recently Knutson et al. (1976) determined the collection efficiency of homogeneous artificial aerosols by natural snow crystals. In both reports the value of collection efficiency was of the order of 10^{-3} to 10^{-4}, although the collecting mechanisms were not clear. It is noted that these values are at least two orders smaller than that estimated from the present work.

As described above, mechanisms as much as possible were considered for explaining the observed high collection efficiency, however, we found no possible mechanism. Recently Gradel and Franey (1973), by the use of methods entirely different from ours, found that the scavenging efficiency of raindrops for the complex natural aerosols exceeds values measured for homogeneous aerosols under controlled laboratory conditions by as much as three orders of magnitude. Taking account of their reports and the results of our measurement, it is strongly suspected that in nature there is an unknown mechanism by which the collection efficiency of aerosols by falling snow crystals or raindrops is considerably increased.

5. Conclusions

It was observed with an optical microscope and an electron microscope that numerous aerosols of submicron size were attached to falling snow crystals; it was concluded that these aerosols were captured by the snow crystals under the cloud base.

It was estimated that the apparent collection efficiency of aerosols by falling snow crystals was as high as near unity, utilizing the mode of size distribution and the surface density of aerosols attached to the surface of the snow crystals.

In order to explain such high efficiency, many possible mechanisms, e.g. impact collision, Facy effect, diffusion (Brownian motion and turbulent motion), and electrostatic force were theoretically estimated, however, these mechanisms were insufficient to explain the high collective efficiency.

It is hoped that all possible mechanisms are reexamined, both theoretically and experimentally, because unknown factors are suspected in natural washout phenomenon.

6. Acknowledgements

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ПРЯМЫЕ НАБЛЮДЕНИЯ АЭРОЗОЛЕЙ, СВЯЗАННЫХ С ПАДАЮЩИМИ КРИСТАЛЛАМИ СНЕГА

В Саппоро в марте 1973 и 1974 гг. прямыми наблюдениями с помощью оптического и электронного микроскопов были обнаружены аэрозоли, связанные с падающими кристаллами. Было определено, что эти аэрозоли были захвачены снежными кристаллами при их выпадении из облака. Поскольку модальный радиус в распределении по размерам аэрозолей, связанных со снежными кристаллами, был практически тем же, что и для распределения Юнге в интервале от 0,1 до 5 мкм, то считалось, что кристаллы снега захватывали аэрозоль с эффективностью, практически одинаковой для прилегающего интервала размеров, что не согласуется с общей теорией эффективности захвата. Эффективность захвата вычислялась также при использовании поверхностной плотности аэрозолей, находящихся на поверхности снежных кристаллов. Результаты расчетов показали, что эффективность захвата была близка к единице.

Все возможные механизмы захвата аэрозолей падающими снежными кристаллами были рассмотрены и проанализированы с целью получить объяснение высокой эффективности захвата, однако, это оказалось безнадежным. Это предполагает, что существуют некоторые неизвестные еще механизмы в естественном вымывании аэрозолей падающими снежными кристаллами.