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Measurement of the Riming Amount on Snowflakes

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Abstract

There are three growth processes of deposition, aggregation and riming in the formation of snow particles. In order to study the riming growth process which is considered to contribute to the snowfall in the seaside area actually, we attempted to develop methods for measuring the riming amount. As a result we established the following methods in which riming amount is represented by the quantitative values such as riming proportion through the disassembly method and filter paper absorption method.

The data obtained in the seaside area were analyzed by these methods. The result is that almost all values of the riming proportion were higher than 50%. Therefore, it is considered that the riming growth process make a remarkable contribution to the growth of snow particles in the clouds over the seaside area.

1. Introduction

It is well known that snow particles grow through the processes of deposition, aggregation and riming. It is very important in the investigations of snow particle formation and precipitation mechanisms to study the ratios of contribution by each process in the growth of a snow particle. But such investigations have been not made as yet. As rain drops do not leave traces of their growth processes, it is difficult to study the ratios of contribution by each process. On the other hand, as snow particles fall to the ground maintaining the degree of deposition growth as the size of snow crystals, the degree of aggregation growth as the number of snow particles constituting an aggregated snow particle and the degree of riming growth as the riming amount, there is a possibility of measuring the ratios of contribution by each process. In this paper we will concentrate on the riming growth process, which is considered to contribute to

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the snowfall amounts in the seaside area, as the main theme.

There are many studies on the riming properties of snow crystals (e.g. Harimaya, 1975), but there are only a limited number of studies regarding the riming amount on snow crystals. For example, Hobbs et al. (1971) classified the degrees of riming into five grades by the coverage of riming and Reinking (1973, 1975) classified them into six grades. Fujiyoshi and Wakahama (1985) unfastened aggregates with a bamboo skewer, then classified the snow particles comprising aggregates into three types according to degree of riming and counted the ratios of snow particle number with each type to the total number. They represented the degree of riming of aggregates by the ratios. In those papers, the riming amount was estimated qualitatively.

In this paper we will attempt to estimate the riming amount on snowflakes quantitatively by the disassembly method and filter paper absorption method. In these methods, the riming amount is represented by riming proportion (the ratio of riming mass to total mass constituting a snowflake) and the measured values by the two methods are compared with each other.

2. Methods

2.1 Disassembly method

The measurement was made as follows. Snowflakes were captured on a piece of board covered with a velvet cloth and one snowflake with mean degree of riming amount was selected as representative. This was disassembled into each snow crystal by a bamboo skewer on a glass plate as carefully as possible so that it would not fracture. Then, all snow crystals constituting one snowflake were photographed. Fig. 1 shows an example of a disassembled snowflake which was collected at 0830 JST 26 January 1987.

Each snow crystal was classified into three types, namely Type I, Type II and Type III as seen in Fig. 1 according to the degree of riming and graupel particles were referred to as Type IV. If the classification corresponds to that by Magono and Lee (1966), Type I corresponds to unrimed crystal and rimed crystal (hereinafter Type I is regarded as the standard that riming amount is zero), Type II to densely rimed crystal and graupellike snow with less riming amount, Type III to graupellike snow with more riming amount and Type IV to graupel.

Then, based on the numbers of each type regarding snow crystals constituting one snowflake, the number ratios of each type were obtained. For example, the measured results on 26 January 1987 are shown in Fig. 2. This figure shows

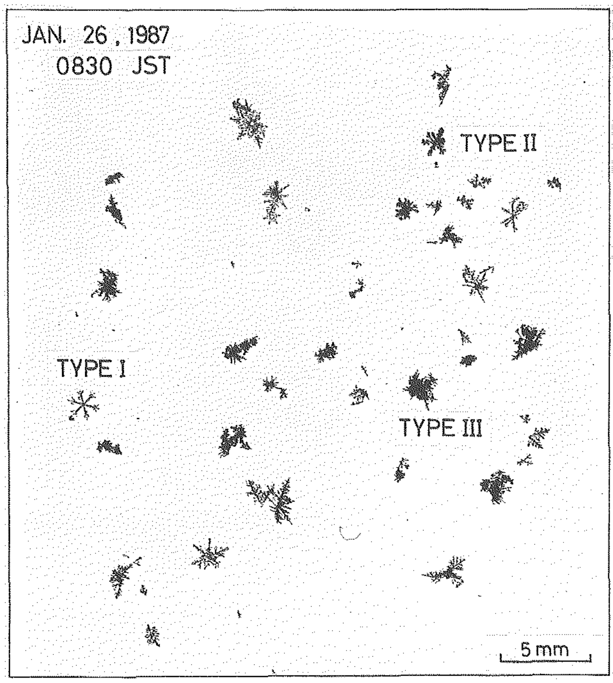

Fig. 1 All snow crystals constituting one snowflake. Examples in each type are shown by names such as Type I, Type II and Type III.

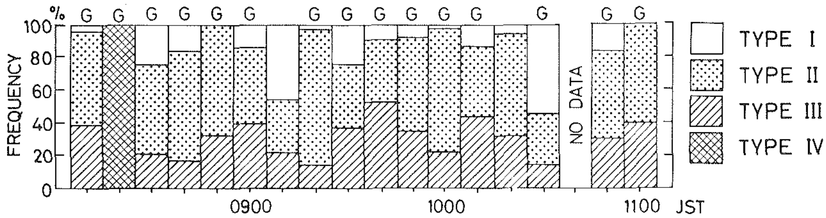

Fig. 2 Time change of the number ratios of each type regarding all snow crystals constituting one snowflake. Open part, dotted part, diagonal part and meshy part represent Type I, Type II, Type III and Type IV respectively. G mark shows graupel particles which fall simultaneously with snowflakes.

the time change of the number ratios of each type. The measurements were made every 10 minutes. Open part, dotted part, diagonal part and meshy part represent Type I, Type II, Type III and Type IV respectively. G mark shows graupel particles which fall simultaneously with snowflakes. It is seen that

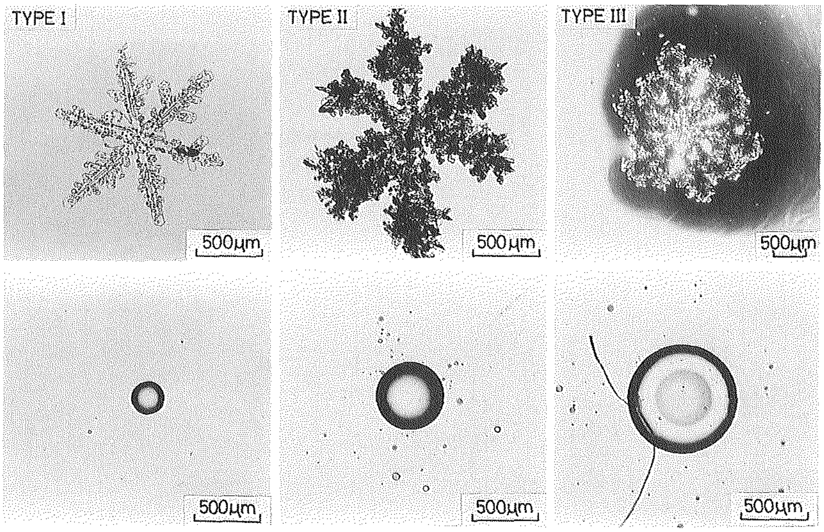

Fig. 3 Microphotographs of each type of snow crystals and corresponding water drops melted in silicon oil.

Type II and Type III were predominant on 26 January 1987.

In this figure which shows only the number ratios of each type, we can not recognize the riming amount quantitatively. Therefore, we will attempt to measure the riming amount quantitatively as follows.

First, the relationships between the diameter and mass of snow crystals should be obtained. In order to measure the maximum diameter of snow crystals, snow crystals were photographed under a microscope. Then, they were melted in silicon oil and photographed again under a microscope in order to measure the mass of snow crystals. Microphotographs of each type are shown in Fig. 3. This measurement was carried out simultaneously during the disassembling of the snowflake.

This measurement was made regarding numerous snow crystals of each type and the values were compiled into the relationships between the diameter and mass of snow crystals regarding each type such as shown in Fig. 4. Open circle, solid circle and solid triangle indicate Type I, Type II and Type III respectively. The empirical formulas between the diameter and mass of snow crystals were obtained by the least square method.

$$\text{Type I}: \; q = 10^{-2.3p^{-0.65}}, \tag{1}$$

$$\text{Type II}: \; q = 10^{-2.1p^{-0.83}}, \tag{2}$$

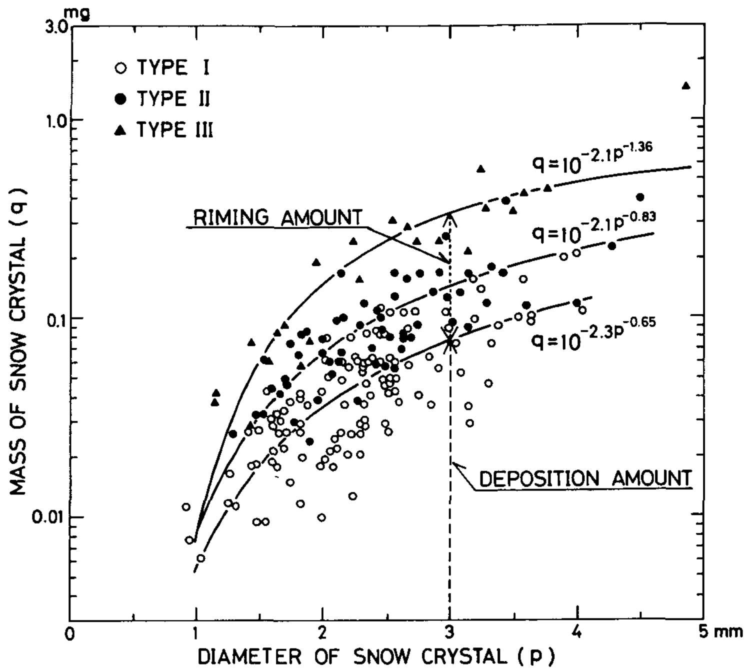

Fig. 4 Relationships between the diameter and mass of snow crystals regarding each type. Open circle, solid circle and solid triangle indicate Type I, Type II and Type III respectively. A broken line and dotted line indicate deposition amount and riming amount respectively.

$$\text{Type III}: \ q=10^{-2.1p^{-1.36}}, \tag{3}$$

where q and p show the mass and diameter of snow crystals respectively.

Next, the riming mass of each snow crystal was obtained using these empirical formulas. If we select a snow crystal of Type III with a diameter of 3 mm for example, the mass is obtained from the empirical formula of Type III as seen in Fig. 4 and the riming mass is estimated from the mass difference between a snow crystal (Type III) and unrimed snow crystal (Type I) with a diameter of 3 mm. Then, each mass and each riming mass were summed up regarding all snow crystals constituting one snowflake and the riming proportion is presented by the ratio of the total riming mass to the total mass constituting one snowflake. In this case, the riming proportion of a graupel particle was assumed to be 100%. Fig. 5a shows the time change of the number ratios of each type regarding all snow crystals constituting one snowflake,

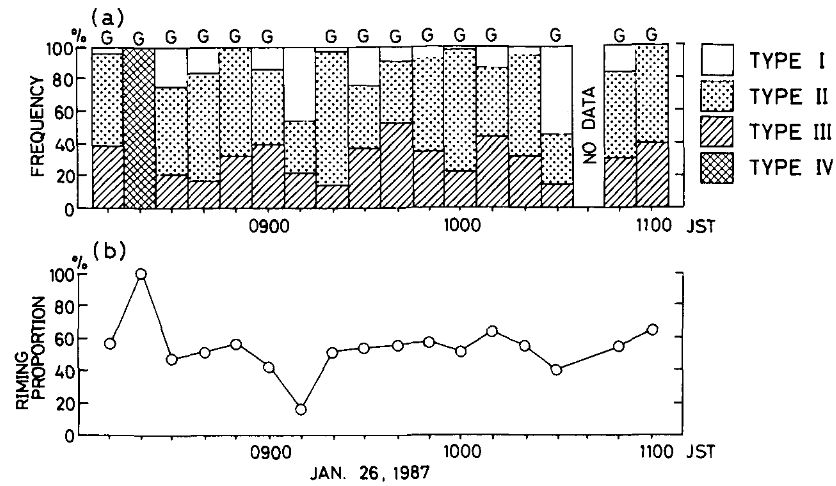

Fig. 5 Time changes of the number ratios of each type regarding all snow crystals constituting one snowflake (a) and of the riming proportion regarding snowflake (b).

whereas Fig. 5b shows the time change of the riming proportion regarding the snowflake obtained by the abovementioned method. It is seen that the figure represents the degree of riming quantitatively.

2.2 *Filter paper absorption method*

No methods for estimating the riming amount on snowflakes are available as yet, thus many kinds of measurement methods have been tested. On the other hand, we should examine the measured values by the disassembly method. Therefore, we attempted to obtain the riming proportion by filter paper absorption method. The method is based on the fact that a snowflake with a much riming amount would be heavier than that with a little riming amount in the case of snowflakes of equal size. The method is as follows. Snowflakes were captured on a piece of the board covered with a velvet cloth and photographed as shown in Fig. 6. Then, the snowflakes were melted by a heater and absorbed by a filter paper. The traces on filter paper are shown in the lower part of Fig. 6 for example.

Then, the diameter and mass of snowflakes were measured from the data obtained by abovementioned method. The graphic data processer system shown in Fig. 7 was used to measure a large amount of data. In this system, the values measured on photographs and filter papers are fed into a graphic data

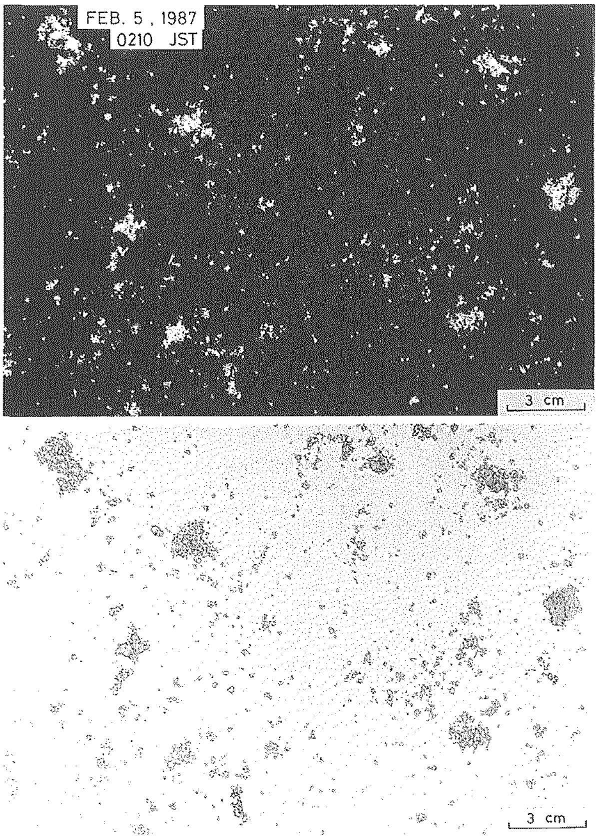

Fig. 6 Photograph of snowflakes (upper) and traces on filter paper of melted snowflakes (lower).

processer by video camera. The graphic data processer measures the area of snowflakes on the photograph and transforms the area into the diameter of circle with an equal area. It measures the area of traces of melted snowflakes on the filter paper as well and transforms the area into the melted diameter of the snowflakes by an empirical formula between the diameter of water drop and the corresponding area of the trace on filter paper.

The measurements were made every 10 minutes during snowfalls and all measured values were compiled to the relationship between the diameter and melted diameter of a snowflake as shown in Fig. 8.

It is seen that the relationship is linear on the graph with logarithm presentation. Unrimed snowflakes are the lightest in the snowflakes with equal

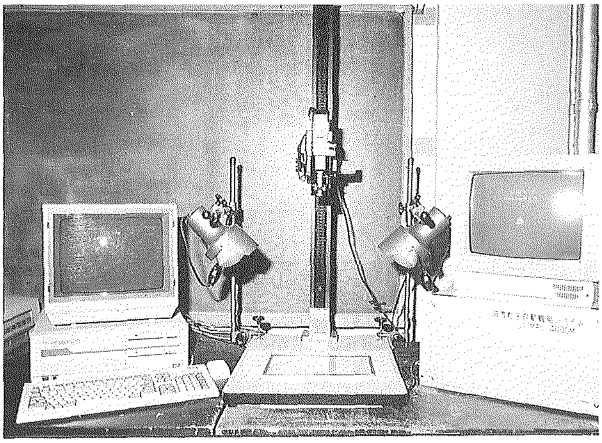

Fig. 7 Graphic data processer system measuring the diameter of snowflakes on photographs and the melted diameter of snowflakes on filter papers.

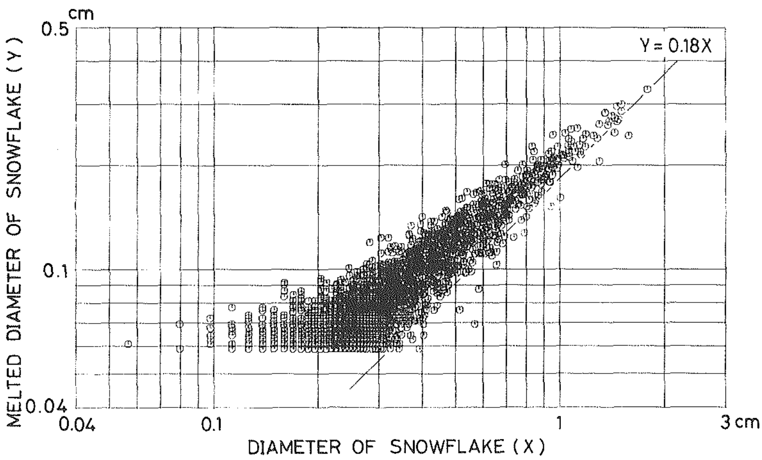

Fig. 8 Relationships between the diameter (X) and melted diameter (Y) of snowflakes.

size, hence the right edge of the extension of measured values may be regarded as the empirical formula regarding the unrimed snowflakes. The empirical formula is represented by

$$Y = 0.18X, \tag{4}$$

where X and Y are the diameter and melted diameter of snowflakes respectively. By using this empirical formula, the riming mass on snowflakes was obtained from the mass difference between the mass of a snowflake and the mass of a unrimed snowflake with an equal diameter. Then, we can estimate the riming proportion by using the mass and riming mass of the snowflake.

3. Results and discussions

The riming proportions by disassembly method were compared with those by filter paper absorption method as seen in Fig. 9. In these measurements, the riming proportion by disassembly method was obtained from one snowflake each time, whereas that by filter paper absorption method was obtained from the mean values regarding some snowflakes with an equal diameter of a snowflake used by disassembly method each time. It may be seen that riming proportions by the two methods show a one-to-one correspondence with some extent.

The riming proportion by the disassembly method was obtained from one snowflake each time, thus it should be examined as to whether it represents the value at that time. The examination was made as follows. The degree of

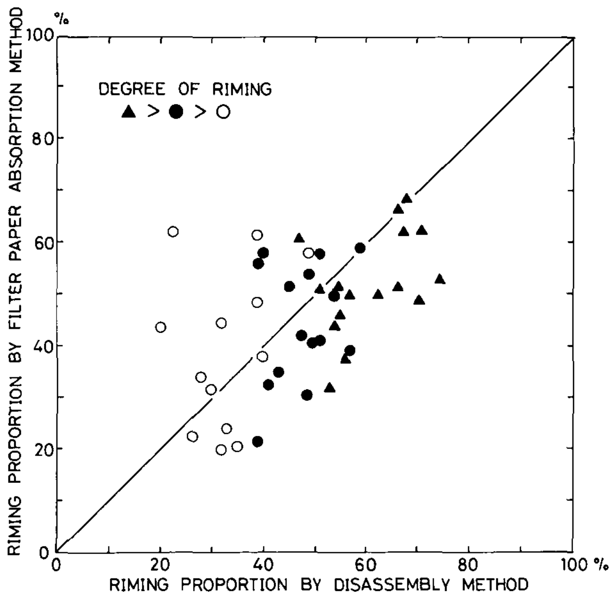

Fig. 9 Relationship between the riming proportions by disassembly method and filter paper absorption method. Solid triangle, solid circle and open circle indicate the degree of riming.

riming was estimated by eye from the photograph of snowflakes fallen on a piece of board covered with a velvet cloth at the time when the riming proportion was measured by the disassembly method. The degrees were represented by solid triangle, solid circle and open circle in Fig. 9. Solid triangle, solid circle and open circle show a high grade, medium grade and low grade respectively. The ranges of high value, medium value and low value measured by the disassembly method corresponded to solid triangle, solid circle and open circle respectively, therefore it can be said that the riming proportion by disassembly method represents the value each time.

On the other hand, as the riming proportion by filter paper absorption method is based on values regarding many snowflakes which fell each time, it would be reliable for the representation of time. But, as the line of relationship between the diameter and melted diameter of unrimed snowflakes was assumed, this method contains some uncertainties. As the observation point Shinoro is in the seaside area about 10 km apart from the coastal line, rimed snowflakes or graupel particles fall frequently. Therefore, these data lack unrimed snowflakes. If observations are made inland, it would be possible to obtain numerous data regarding unrimed snowflakes. In future, if an observation is made inland and numeous data regarding unrimed snowflakes are obtained, the filter paper absorption method will be established. From consideration abovementioned, the riming proportion by the disassembly method was adopted

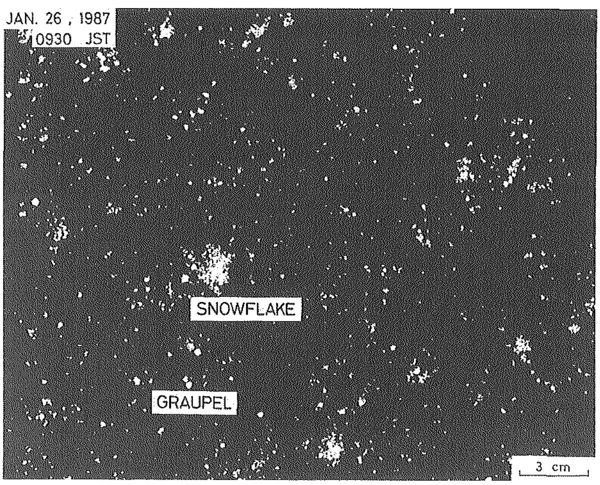

Fig. 10 Photograph showing the fact that snowflakes and graupel particles fall simultaneously.

hereinafter.

We have been discussing about the riming proportion of only snowflakes from the outset. It happens frequently as seen in Fig. 10 that snowflakes and graupel particles fall simultaneously. In that case, we should incorporate the effect of graupel particles to the riming proportion. The procedures are as follows. We count the number (Ns) of snowflakes and the number (Ng) of graupel particles captured on a piece of board covered with a velvet cloth each time. If we adopt the riming proportion (R %) by the disassembly method and assume the riming proportion of graupel particles to be 100%, we obtain

$$R' = \frac{R \cdot Ns + 100 \cdot Ng}{Ns + Ng} \ (\%), \tag{5}$$

where R' % indicates the riming proportion incorporating the effect of graupel particles.

The final results are shown as follows. Fig. 11a shows the time change of the number ratios of each type regarding all snow crystals constituting one snowflake, and Fig. 11b shows the time changes of the riming proportion regarding snowflakes (○), and of the riming proportion incorporating effect of graupel particles (●). Through the procedure abovementioned, we can obtain the riming proportion every 10 minutes. In the case of snowfall on 26 January 1987,

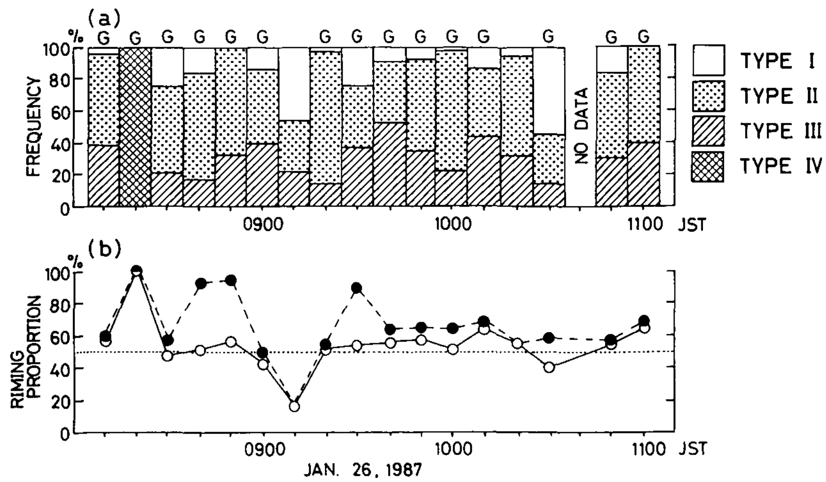

Fig. 11 Time changes of the number ratios of each type regarding all snow crystals constituting one snowflake (a), of the riming proportion regarding snowflake (○) and of the riming proportion incorporating the effect of graupel particles (●).

almost all values of the riming proportion were higher than 50 %, therefore it is considered that riming growth process contributed to the growth of snow particles in the clouds over the seaside area remarkably.

4. Conclusions

In order to study the riming growth process in the formation of snow particles, we developed methods for measuring the riming amount in which the measured values are represented by the quantitative values such as riming proportion. One is the disassembly method and the other is the filter paper absorption method.

The observed data, which were obtained at Shinoro in the seaside area about 10 km apart from the coastal line, were analyzed by the method to obtain the riming proportion. The result is that almost all values of the riming proportion were higher than 50%. Therefore, it is considered that riming growth process contributes to the growth of snow particles in the clouds over the seaside area remarkably.

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