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An Observation of Snow Crystals and Their Mother Cloud

(Investigation of Natural Snow Crystals V)

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Abstract

A three dimensional observation network was organized for cloud and snowfall observations on the west coast of Hokkaido. From the horizontal and vertical distributions of cloud cover and snow crystals, a mother cloud from which the snow crystals were released was selected and observed. Thus it was ascertained that local heavy snowfalls at the end of the north-west monsoon period originated at first from the lower stratocumulus of band structure and thereafter was increased by an orographic convergence effect.

1. Introduction

For recent several winter seasons, investigations on the growth of natural snow crystals were carried out by the Cloud Physics Group[1),2),3),4)] in the vicinity of Mt. Teine by observing the vertical distribution of snow crystals, and it was found that Nakaya's *Ta-s* diagram[5)] for the growth of artificial snow crystals was applicable to natural snowfall phenomena. However, in these observations it was noted that the identification of snow crystals and their mother cloud from which the snow crystals were released was insufficient, and that it was difficult to measure the aerological condition of the mother cloud directly, even when the cloud was identified with certainty as the source of the snowfall. Hence, simultaneous observation of snow crystals and their mother cloud became desirable in order to understand the snowfall phenomena completely.

Generally the snowfall phenomenon has a fairly wide scoped range, and snow crystals are distributed far from their mother cloud. Furthermore the direction of the drifting crystals changes widely depending on the prevailing wind direction. In order to cope with this situation, a fairly wide but dense

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observation network was organized in the Ishikari Plain, at the foot of Mt. Teine to observe the horizontal structure of the snowfall phenomena. For the vertical structure, an observation aircraft, radiosonde sounding, snow crystal sonde sounding together with an observation point at the summit of Mt. Teine (1023 m) were used.

In the Ishikari Plain hitherto, the Sapporo Meteorological Observatory[6] has studied several heavy local snowfalls, and Higuchi[7),8] made his observation of the horizontal distribution of snow crystals. From the results of the Sapporo Meteorological Observatory, heavy local snowfalls occur suddenly at the end of the north-west monsoon period and the difficulty to forecast such sudden snowfalls was noted. The snowfalls in this plain are interesting and convenient for observation as will be reported later.

2. Observation method

The Ishikari Plain is situated between two mountain regions. In the winter season, north-west monsoons prevail which brings in moist air from the Ishikari Bay, on the Sea of Japan. With the cooperation of 18 high schools an observation network was organized in February, 1963 on the Ishikari Plain. The distribution of observation points are shown in Fig. 1. In the figure, double circles indicate the main observation points which were manned by Cloud Physics Group members.

Observation items and data gathering organization are shown in Table 1.

2.1 *Cloud observation*

The photographic observations of clouds were made at 0900 and 1500 JST everyday at four main observation points: Mt. Teine, Ishikari, Tobetsu and Iwamizawa by means of panoramic pictures. Information concerning the cloud height were obtained from the vertical distributions of air temperature and humidity which were obtained by rawinsonde and radiosonde sounding. When clouds were of layer type, the estimation of the height of cloud base and cloud top was possible. Thus, as a result of estimations of cloud height, the horizontal distribution of cloud cover over Ishikari Plain was analyzed by use of photographs of clouds taken at the four main observation points. The aerial pictures of clouds taken from the aircraft was also useful to determine horizontal cloud distribution.

During the daytime observation periods; 0800–1000 and 1400–1600, a 16 mm time-lapse movie camera worked at the summit of Mt. Teine, pointing towards the coast of the Ishikari Bay. When there were no clouds around the

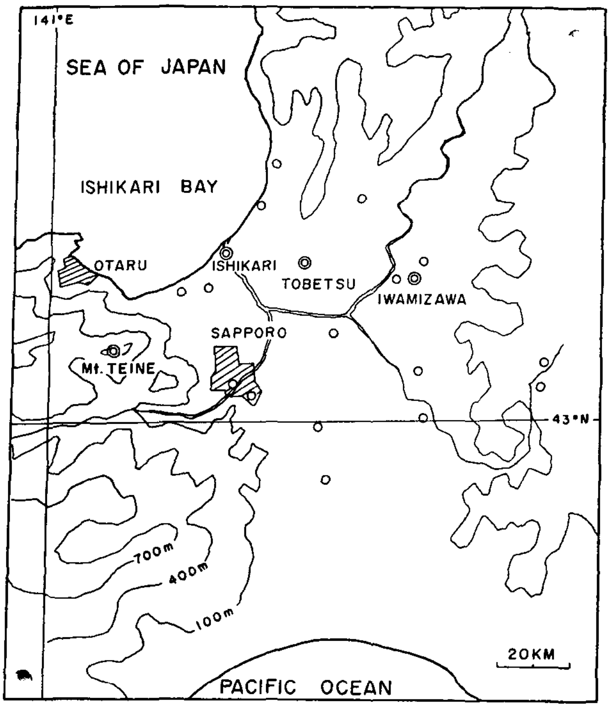


Fig. 1 Distribution of observation points

summit, the movie camera recorded good pictures which showed clearly the movement and the change in shape of clouds over the sea shore.

2.2 *Snow crystal observation*

Microscopic photographs and replicas of snow crystals were taken at the four main observation points at intervals of 15 min. during the observation periods: 0800–1000, 1400–1600 and 2000–2200. The replica observations of snow crystals were made at 0900 and 1500 at the 18 high school observation points.

A recording machine of snow crystals in clouds was specially devised by one of the authors and Tazawa[9]. It consists of a rolling film on which replicas of snow crystals are set by means of polyvinylformvar solution. This apparatus is referred to as a "snow crystal sonde" in the present paper. The snow crystal sonde was released from the observation aircraft on a marked cloud simultaneously with the release of a dropping radiosonde. A total of seven snow crystal sondes were released and three of them were recovered on

Table 1. Data-gathering organization

Observation points	Items of observation	Observers
Chief		Choji Magono
Mt. Teine	16 mm time-lapse movie of clouds Photograph of clouds Microscopic photograph of snow crystals	Katsuhiro Kikuchi
	Temperature and humidity of air Replicas of snow crystals	Seiichi Tazawa Tatsuo Endo
Ishikari	Microscopic photograph of snow crystals	Kenji Ishizaki
	Photograph of clouds	Tatsuo Endo Keiji Higuchi
	Microchange in air pressure	Koji Yamamoto
	Replicas of snow crystals Temperature and humidity Atmospheric electric field Snow gauge	Norihiko Maeda Koji Yamamoto Kazuko Matsuo
Tobetsu	Sub chief	Keiji Higuchi
	Microscopic photograph of snow crystals Photograph of clouds	Seiu Lee
	Radiosonde sounding	Kunio Enoki Toshiyuki Kasai
	Temperature and humidity of air Atmospheric electric field Snow gauge	Seiu Lee Toshiyuki Kasai Yoshiharu Shiotsuki
Iwamizawa	Microscopic photograph of snow crystals	Teisaku Kobayashi
	Photograph of clouds Replicas of snow crystals Atmospheric electric field	Norikazu Maeno Norihiko Maeda
Aircraft	Aerophotograph of clouds	Choji Magono Keitaro Orikasa
	Drop radiosonde sounding Snow crystal sonde sounding	Keitaro Orikasa Tadashi Kimura Seiichi Tazawa
Sapporo	Rawinsonde sounding	Sapporo Meteorological Observatory
Ishikari Plain	Replicas of snow crystals	12 high schools and 6 middle schools
Ishikari Plain	Wind	56 railroad stations

Remarks: Some of observers altered their items of observation during the observation period.

the ground surface about 20 kilometers leeward of each release point.

2.3 *Vertical profile of clouds*

Routine rawinsonde soundings were made at Sapporo at 0900 and 2100 everyday. And radiosonde soundings were made at Tobetsu mainly at 1500 by means of the so called UD-sonde designed by Kimura[10]. The UD-sonde sends signals such as produced by usual radiosonde during its ascent. When it reaches the 500 mb level (about 5000 m altitude), it is released and begins to fall down at a steady speed regulated by a parachute, transmitting signals in its descent.

In addition to this, dropping radiosonde soundings were made from the aircraft simultaneously with the snow crystal sonde soundings, but this work was unsuccessful because in almost all cases the parachute failed to work as expected.

2.4 *Other observations*

General surface meteorological observations were made at the four main observation points.

The time change in atmospheric electric field was recorded by electrometers of Bendorff type at the main observation points, however, since the points were too far spaced from each other, the correlation of the change in the electric field with the movement of clouds was unsuccessful.

Snow gauges of heating type were set at the main points, but the snowfall intensity was too small to be detected by the gauges, because in almost all cases the snow which fell on the gauges evaporated before being detected. Snowfalls during the observation period were not heavy.

3. Results

As described above, various types of simultaneous observations were continued for a period covering three weeks in February, 1963, but due to various reasons complete data covering all observation items were hard to obtain. Particularly observations by light Cessna type planes were difficult during snowfalls when observations were desirable. Thus, only the results obtained on the morning of 16 February will be described below.

3.1 *Synoptic situation*

According to the surface weather map of 0900, 16 Feb. 1963 in the upper part of Fig. 2, it would seem that fine weather prevailed over the entire area of Hokkaido, but actually a considerable snowfall was observed in the

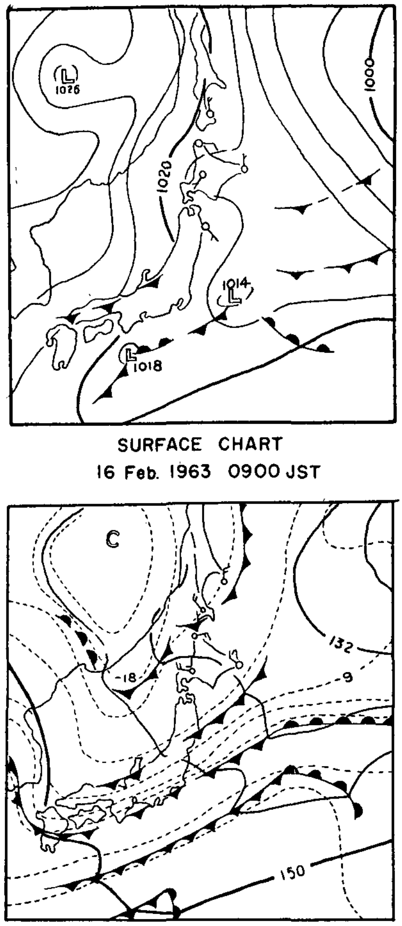


Fig. 2 Weather maps at surface and 850 mb 0900, 16 Feb. 1963

Ishikari Plain. According to studies by the Sapporo Meteorological Observatory, such snowfalls are not unusual at the end of the north-west monsoon period after the passing of a cyclone. As for the upper weather situation, Hokkaido was between two cold fronts as seen in the lower part of Fig. 2, but it is considered by the distribution of isotherms that the air temperature at 850 mb layer was horizontally uniform over the Ishikari Plain. As far as the weather maps are concerned, the weather was considered fine and quiet in the observation area. Therefore, the snowfall observed was only of local type, although such local snowfalls are frequently observed on the west coast of Hokkaido Island.

3.2 *Analysis in meso-scale*

Judging from the usual weather map in Fig. 2 a snowfall was not expected in the observation area. Hence, an analysis in meso-scale was made. The result is shown in Fig. 3. The pressure pattern at the surface in the figure shows that a small depression existed near the west coast to the north-west of Ishikari Plain. This depression might have been produced by the so called west-high, east-low pressure pattern that exists in the winter season and by cold air which was produced during the night time over the inland. From the pressure pattern in meso-scale it was expected that a northerly wind would came in from the Ishikari Bay to Ishikari, and collide with the cold air blowing out from the inland. This is as actually seen in the distribution of surface wind shown in Fig. 4. It is also seen in the figure that the wind of the two systems joined each other, then followed the valley to the north-east of the observation area. This wind course is shown by thick black arrows. The direction of upper winds between 1000 and 2000 m levels was north-west as shown by the white arrow.

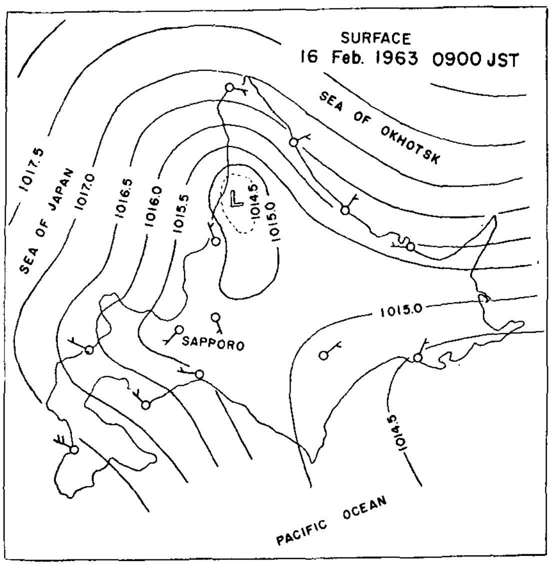


Fig. 3 Pressure pattern in meso-scale

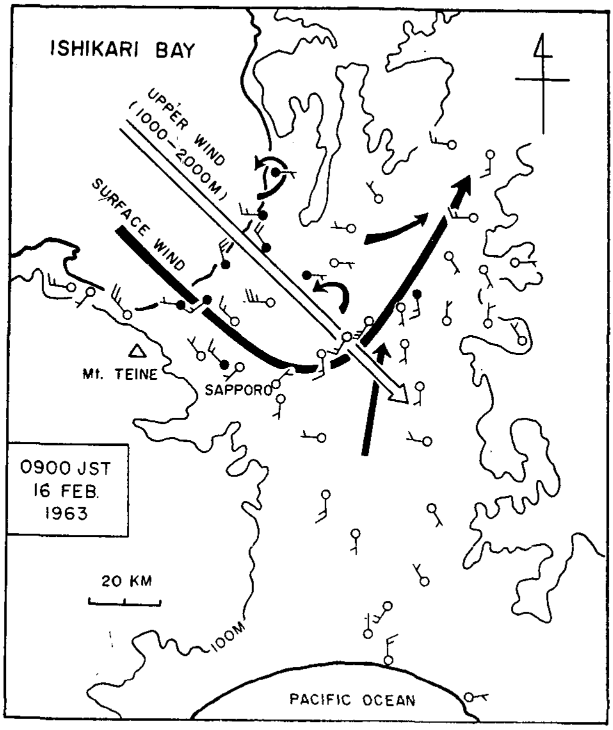


Fig. 4 Surface wind distribution

As far as the observation area is concerned, the winds were northwesterly both at the surface and at the upper levels. Since the observation area is located to the south-east of Ishikari Bay, it is considered that all of the snow crystals observed were borne in from the north-west, from the sea.

3.3 *Distribution of snow crystals*

Snow crystals observed are shown by microscopic photographs in Pl. I. In the plate, each photograph of snow crystals are attached right under the name of observation points where the snow crystals were observed. As seen in the left bottom of the plate all the snow crystals at the summit of Mt. Teine were of beautiful plane type (hexagonal, plate, stellar, sector and dendritic). It is also noted that they carry no supercooled cloud droplets on them.

Around 1100 hour, a snow crystal sonde was released on a stratocumulus cloud over Ishikari Bay from the aircraft at a height of 2900 m as shown by parachute symbol in Pl. 1. It flew to the south-east and was found on the

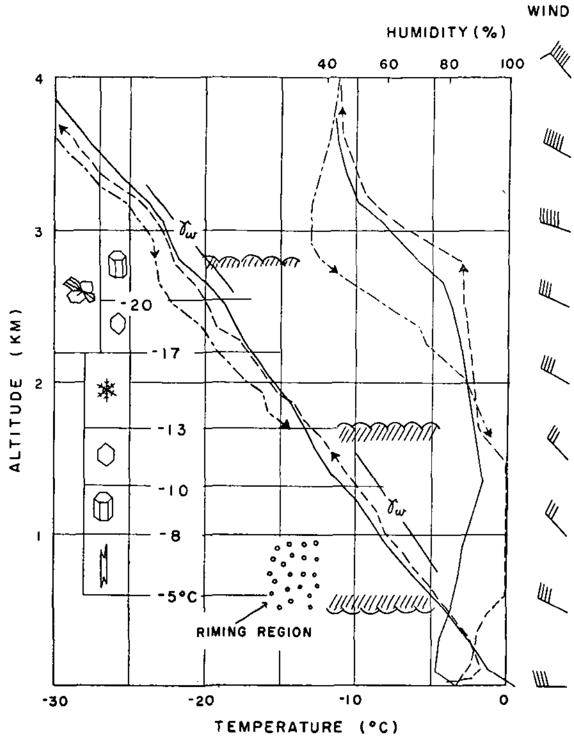
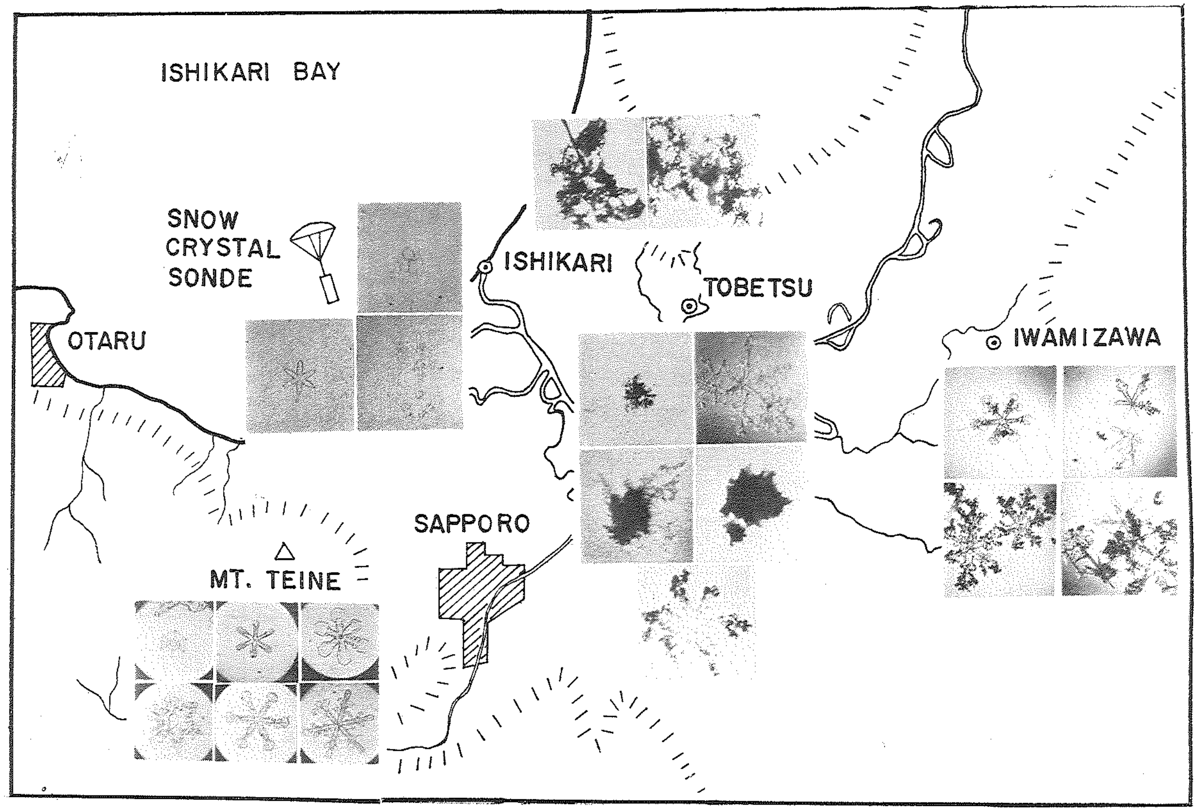


Fig. 5 Vertical distributions of snow crystals to temperature and humidity

sea shore. According to the result of analysis of the snow crystal sonde sounding, the sonde caught sectorlike crystals at 1800 m, stellar crystals at 1400 m and dendritic crystals at levels between 1000–1350 m levels respectively. As may be seen all the snow crystals were of plane type and they do not seem to be rimed, although the fine structure of the snow crystals was lost from the surface of their replicas. The fact that snow crystals observed at the upper levels were not rimed, shows a predominant contrast with rimed crystals observed at the surface as described below.

The snow crystals observed at Ishikari were rimed dendritic and rimed radiating type crystals, as shown in the upper part of Pl. I. The crystals at Tobetsu were graupel, graupellike crystals, rimed crystals with needles and dendritic crystals as shown in the center of the plate. The crystals at Iwamizawa were dendritic crystals and rimed crystals, as shown in the right part of the plate. It may be seen that almost all of the snow crystals observed

Pl. I Horizontal distribution of snow crystals



Observed snow crystals are shown with microscopic photographs under names of observation points.

at the surface of Ishikari Plain were more or less rimed. Since the shape of snow crystals recorded by replica method were almost the same as those shown by microscopic photographs, they are not in Pl. I, however no snow crystals were observed along the foot of Mt. Teine region between Otaru and Sapporo.

It is noted that the type of snow crystals observed at the levels higher than 1000 m were all plane type and not rimed, but snow crystals observed at the surface of Ishikari were all rimed and some of them had spacial structure. It is also noted that the snow crystals observed near the sea shore were rimed more extensively than those at inland areas. These facts suggest that the riming of the snow crystals occurred at levels lower than 1000 m and the supercooled droplets for the riming were supplied from the sea. The rate of snowfall was 10–20 mm. hr^{-1} in depth.

3.4 *Vertical structure of snow clouds*

In the observation on the morning of 15 Feb., three vertical profiles of meteorological condition were available. One was obtained by rawinsonde sounding at Sapporo, the other two were obtained by the UD-sonde sounding at Tobetsu. The results are shown in Fig. 5. In the figure, the vertical axis shows the height above sea level. The horizontal axes respectively show air temperature (bottom) and relative humidity with respect to water surface (upper). The vertical distribution of wind measured by the rawinsonde at Sapporo is shown on the right side of the figure. The data obtained by the rawinsonde at Sapporo are shown by solid lines. The data obtained in the upward course and in the downward course of the UD-sonde are shown by broken and chain lines respectively. The upward and downward course soundings are also distinguished in the figure by the direction of arrows.

As seen in the figure, the temperature distributions at altitudes lower than 3000 m in the three courses show that the temperature gradient was almost the same as the wet adiabatic line γ_{ω} shown by a straight line. This means that vertical mixing was sufficiently made at levels lower than 3000 m, because as stated below, the air was saturated at these levels.

The vertical distribution of relative humidity in the upward course at Tobetsu shows that air at levels higher than 600 m was saturated with respect to water surface. This indicates that the cloud base was about 600 m high, and the cloud was composed from supercooled droplets. The height of the cloud base which was determined by visual observation was 500 m as shown by cloud base symbol in Fig. 5. Considering the time lag of the hygrometer of the UD-sonde, this difference in the cloud base is reasonable, and is considered rather small. The moist level ranged up to about 1500 m height, whereupon the humidity in the upward course decreased rapidly. On the other hand the humidity in the downward course showed a rapid increase from around this height, but unfortunately after passing this height, the UD-sonde stopped transmitting signals. Considering the changes of humidity with height, it was determined that the top was at 1700 m, taking into account the time lag of the hygrometer.

At the 2700 m level, the humidity curve in the upward course decreased again rapidly, where as the curve in the downward course showed a rapid increase at this level. Therefore it is considered that this 2700 m level was the top of an upper cloud layer which was very shallow as determined by visual observation. Another reason for this estimation is that this level agrees with that of the temperature inversion. The difference in humidities in the upward and downward courses may have resulted from the time lag of the hygrometer of the UD-sonde.

The temperature range of snow crystal growth of various shapes determined by Nakaya[5] is represented on the left side of Fig. 5. If such clouds as described above existed to the windward of the observation area, snow crystals of such shapes as shown here could be expected to be observed. Concerning this point considerations will be made after the analysis of cloud distribution.

Wind speed ranged up to 3–10 $m \cdot sec^{-1}$. The higher the level, the greater the wind speed except at sea level. It is noted that there was no maximum in the vertical distribution in speed at levels lower than 4000 m. Wind direction was all westerly, as seen on the right side of Fig. 5.

3.5 *Cloud distribution*

Panoramic pictures of clouds which were taken from the four main observation points and from the observation aircraft are shown in Pl. II, III, IV and V. The horizontal direction of the picture is shown under the corresponding pictures.

The pictures in Pl. II from Mt. Teine show that clouds came in from Ishikari Bay to Ishikari Plain (from left to right). From the change in shape of the clouds, it is understood that shortly after passing over the sea shore the clouds changed to snow clouds from water clouds, and snow crystals were borne inland as a virga. The cloud top is estimated to be at about 2000 m borne which is somewhat higher than the summit of Mt. Teine (1023 m). Another cloud system higher than 2000 m is seen at a level of around 3000 m in height.

The picture from Ishikari in Pl. III shows clouds of stratocumulus type to the west and the east. They were seen moving in from the sea to the south-east. Fairly heavy snowfalls are seen to the west under the cloud which is the same cloud as those presented in Pl. II. The picture from Tobetsu in Pl. IV shows three bands of clouds which extended from north to south. At this time the clouds were already glaciated, namely changed to snow clouds. The fine streaks of the clouds may have consisted of flowing snow crystals. Pictures in Pl. V show aerial photographs which were taken at about 11^h00^m from the observation aircraft at a 5000 ft height above Mt. Teine. Although the time when the pictures were taken as a little later than the observation period, the pictures may give some information for the analysis of cloud distribution, because the cloud system was fairly steady on this day. It may be seen in the pictures that along the north-east end of the Mt. Teine region there was a long thin fine area between the cloud regions over Mt. Teine region and over Ishikari Plain. The clouds over the plain were stratocumulus. The top of the cloud was at about 2000 m, and a few clouds of anvil type were seen isolated on the stratocumulus. From these pictures, it may be seen that the height of the stratocumulus was considerably lower than the flight altitude of 5000 ft and the height of the anvil clouds were considerably higher than 5000 ft. Considering the stratificating property of atmosphere, the height of the anvil clouds may be equal to that of the temperature inversion shown in Fig. 5.

Considering the entire data on cloud distribution and vertical profile of clouds obtained hitherto, it was estimated that the height of the top of the lower stratocumulus was 1700 m and the height of the upper cloud was 2800 m respectively.

On the basis of these assumptions for cloud height, the horizontal distribution of clouds was determined as shown in Fig. 6 by means of aerial photographs in Pl. V. In the figure, solid lines with white dots show the edge of the lower cloud-cover of stratocumulus type with a 1700 m height, and the chain line with triangles shows the edge of the upper cloud layer with a 2800 m height. The latter cloud layer had no relation with the present observation of snow crystals, because it was located to the leeward of the observation area. Cloud distribution was also analyzed by the use of panoramic pictures in Pl. II, III and IV. Thus the edge of the lower cloud as shown by solid line with black dots was determined. The sea shore line under the cloud-cover is shown by a dotted line. In Fig. 6, it may be seen that the edges of the cloud-cover determined by the aerial photographs and the panoramic photographs

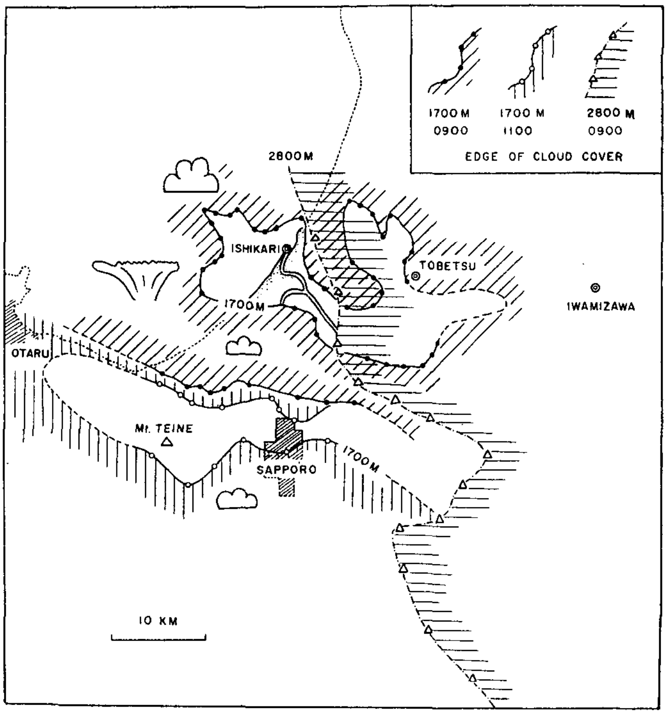


Fig. 6 Horizontal cloud distribution

at the surface agree fairly well with each other, although the former were taken about one hour after the latter. In any event it may be seen that at least two bands of stratocumulus extended from the bay to the plain and two long clear areas of band shape existed over Sapporo and Ishikari. One of the clear area presumably corresponds to the no-snowfall-region around Sapporo described in 3.3.

3.6 *Horizontal falling path of snow crystals and cloud-cover*

The fall velocity of snow crystals of various types has already been studied by Nakaya[11] and one of the authors[12]. By utilizing the results of these studies for fall velocity and the wind velocity made here, the horizontal falling path of snow crystals observed was traced as shown by arrows in Fig. 7. The type of snow crystals are shown by symbols at the site of observation. The black dots show the expected site where snow crystals commenced to be born. The series of white dots near the parachute symbol indicate the

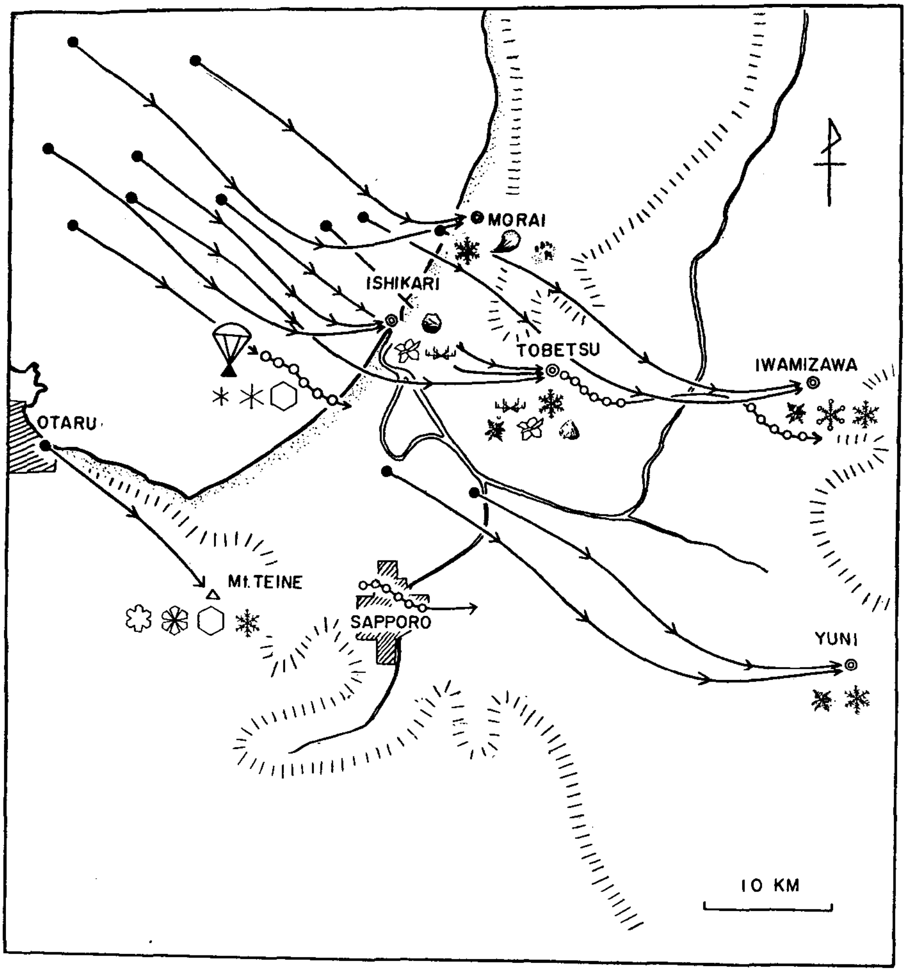


Fig. 7 Horizontal falling path of snow crystals

horizontal falling path of the released snow crystal sonde. And the series of white dots near Sapporo, Tobetsu and Iwamizawa indicate the ascending course of a rawinsonde from Sapporo, the upward and downward course of the UD-sonde from Tobetsu, respectively. It is considered from the ascending course of the rawinsonde from Sapporo that the sonde failed to pass through actual cloud layers. This may be the reason why the humidity obtained by the sonde was not saturated as seen in Fig. 5.

It may be clearly seen that almost all originating points of the snow

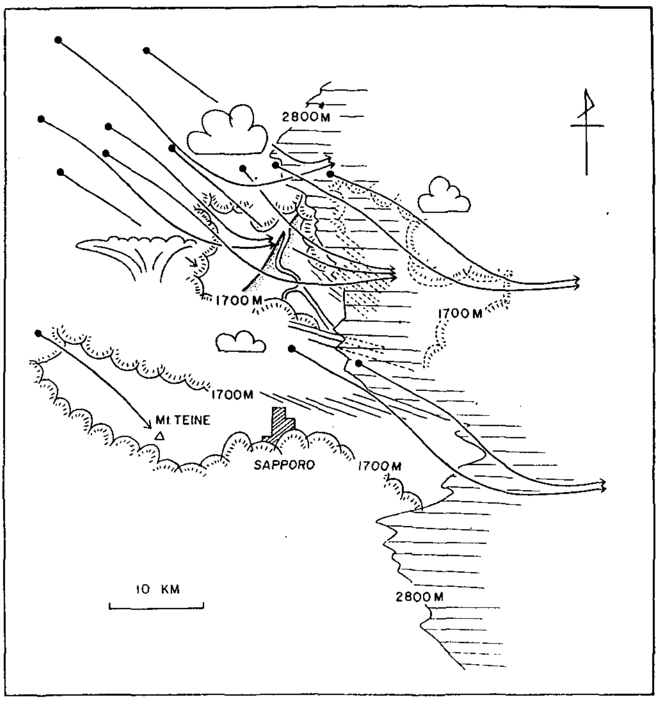


Fig. 8 Horizontal cloud distribution and falling path of snow crystals

crystals observed, were over the Ishikari Bay. This suggests that almost all the snow crystals which are related to the present observation, were already produced over the sea before the clouds penetrated the air over the Ishikari Plain, because heavy snowfalls were observed only near the sea shore and it was slight as it came inland.

The horizontal falling path of snow crystals and the horizontal distribution of the cloud-cover are shown overlapping in Fig. 8. It may be seen in the figure that all originating points of the snow crystals were limited to the range of the lower cloud layers. This is a reasonable and expected result. The elongated snowfall area between Ishikari and Iwamizawa must have originated in the upper left band shaped cloud. Thus the mother cloud from which the snow crystals fell, were determined. However the radiosonde from Tobetsu and the rawinsonde from Sapporo failed to pass the more important parts of the mother cloud, but merely passed through the leeward end of the cloud. Therefore further consideration is required on this point.

The mother cloud of snow crystals was thus determined by the horizontal distribution of cloud-cover, however it becomes necessary to compare the height of the mother clouds with that expected from the shape of snow crystals, in other words, considerations on the vertical structure of clouds is further required.

4. Vertical structure of clouds related to the shape of snow crystals

Ishikari, Tobetsu and Iwamizawa are located on a line parallel to the prevailing westerly wind direction; from NNW to SSE. A vertical cross-section on the line as shown in Fig.9 is assumed in which the horizontal axis indicates the distance from Iwamizawa. The upward and downward courses of the UD-sonde are shown by thick solid lines in the right part of the figure. The cloud height which was estimated from the data obtained by the UD-sonde sounding is shown in the right part. It is considered that the estimation of cloud height is fairly accurate for the cloud over the inland area, but not quite so accurate for the cloud over the sea, because the UD-sonde passed through a cloud over the inland area.

The shape of snow crystals observed at the surface are shown by symbols near the location where they were observed. They were more or less rimed as described in 3.3. The vertical falling path of the snow crystals can be estimated by the use of vertical wind velocity and of falling velocity of crystals of each shape in a manner similar to the case of the horizontal falling path. The height of each snow crystal can be estimated from each original shape. In the present case they all originated from sector or dendritic shape. The vertical paths thus obtained are shown by thin solid lines in Fig. 9. Each black dot at the upper end of the line indicates the estimated height of the originating point of each snow crystal.

Although Mt. Teine and the descending course of the snow crystal sonde were not in the same plane as the cross-section, the vertical falling path of snow crystals observed there are superimposed in the same figure as shown by thin broken lines, because these snow crystals are considered to belong to a cloud system similar to the previous clouds. The thick broken line indicates the vertical components of the descending course of the snow crystal sonde to the cross-section.

In Fig. 9, it is noted that almost all of the heights of originating points of snow crystals are fairly higher than the top of the lower cloud-cover (1700 m) of stratocumulus type which was estimated from the data presented

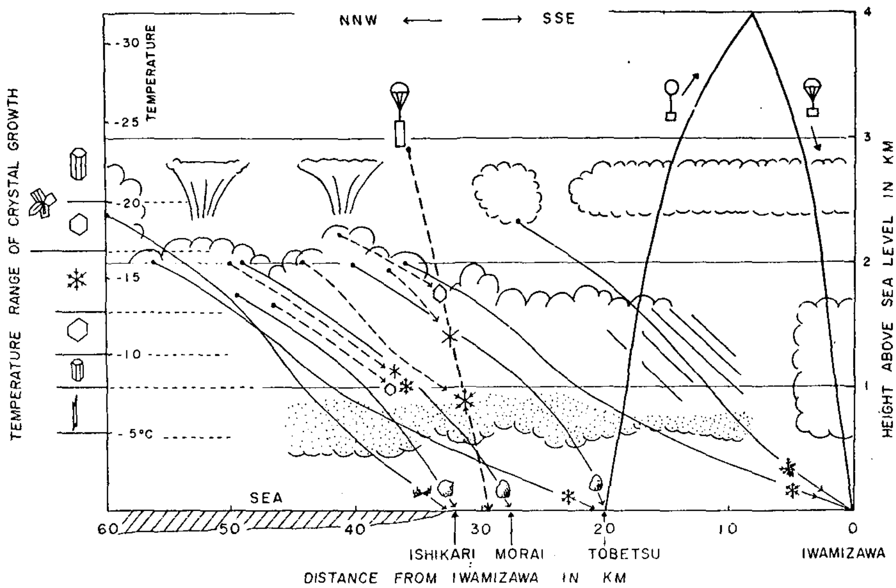


Fig. 9 Vertical structure of snow clouds and falling path of snow crystals

by UD-sonde. They ranged from 1800 m over Tobetsu to 2200 m over the sea. When Nakaya's *Ta-s* diagram for the estimation of cloud height is adopted, temperature range of the cloud as shown in the left part of Fig. 9 may be obtained.

It is noted again that snow crystals observed at levels higher than 1000 m were all of beautiful plane type and not rimed. In contrast with this, snow crystals observed at the surface were graupel or rimed crystals, although the grade of riming was small inland. This suggests that supercooled cloud droplets were caught within a cloud layer lower than 1000 m as shown by the dotted area in Fig. 9. The cloud layer which contributed to the riming seemed to decrease in its thickness as it came inland, because the grade of riming was slight inland, and graupel were observed only near the sea shore observation points, i.e., Ishikari, Morai and Tobetsu, however it should be noted that a few anvil clouds were observed near the originating point of the graupel as shown in Fig. 9.

Considering the distribution of snow crystals, cloud and vertical profile of meteorological condition, a vertical structure of snow cloud around the sea shore was obtained as shown in Fig. 9.

5. Considerations

The results obtained are summarized as follows:

1. At the end of monsoon period, it was recognized that an elongated snowfall area near the coast of Ishikari Plain was produced with certainty by a stratocumulus of band feature on the sea to the windward of the snowfall area. The directions of the elongated snowfall and the band of altocumulus were parallel to the direction of the prevailing wind.

2. The stratocumulus became active and changed from a water cloud to a snow cloud (i.e., nimbostratus) above the sea shore or above the sea near the sea shore, then it diffused as flowing snow crystals and disappeared inland. This change in cloud form corresponds to the horizontal distribution of snow crystals in which graupel and much rimed snow crystals were observed near the sea shore, but the grade of riming of crystals were slight inland, and the change in cloud form corresponds to the vertical distribution in which snow crystals observed at levels higher than 1000 m were not rimed.

5.1 *Local elongated snowfall area*

Concerning the local elongated snowfall area, the Sapporo Meteorological Observatory[6] considered that such a snowfall is produced by the so-called orographic "shoulder effect" or convergence effect. On the other hand, Higuchi[13] pointed out that such a snowfall generally originates in snow clouds of band structure which is presumed from Kuettner's study[14].

The precipitation area frequently has a band feature as generally seen in radar echo, and the cloud pattern has also a band structure, the direction of which is parallel or perpendicular to the direction of wind shear, depending on the intensity of the wind shear. It is therefore considered that the elongated snowfall area may have originated in clouds of band structure. However from this consideration only, it is impossible to explain why such a snowfall occurs predominantly in the plain area, particularly near the sea shore locally, because there is not appreciable increase in elevation at the coast of the Ishikari Plain.

The clouds in the north-west monsoon period usually are relatively low. The cloud layer observed in the present work was also low; ranging from 500 m to 1700 m in height. The two mountain regions (1000–1400 m altitude) may act as a barrier for such a low cloud. It is therefore considered that such low air layer receives a strong orographic effect which means here the local horizontal convergence rather than the local ascending air current over the mountain slope. In the present observation area; Ishikari Bay and Plain, the orographic situation if quite favorable for producing the convergence effect for the north-westerly wind, because the area opens to the north-west and lies between two mountain regions as pointed out by Sapporo Meteorological Observatory. In the same manner, plains which are situated in a similar manner on the west coast of Hokkaido have heavy local snowfalls at the end of the monsoon period. We are of the opinion that some groups of stratocumulus are produced over the west part of the Japan Sea far from the coast of Hokkaido, such a cloud distribution was ascertained by recent pictures from TIROS. These have band feature as a character of air layer under a strong wind shear, although no wind speed maximum in the vertical distribution was recognized at the present observation. When one of the band type altocumulus lands in Ishikari Plain (in some case two bands), it is subject to the convergence effect around the coast. As a result of the convergence, an ascending air current is produced in it and it becomes a nimbostratus, which then brings local snowfall areas stretching parallel to the wind direction near the sea shore or to the lee of the cloud.

5.2 *Distribution of rimed snow crystals*

Concerning the horizontal distribution of rimed snow crystals, the authors are of the opinion that. When stratocumulus exists above the sea, it may be entirely composed of supercooled cloud droplets, in other words it might be a water cloud. When the cloud is activated by ascending near the sea shore, ice crystals of hexagonal shape would be born at the top of the cloud, because air temperatures at that level were about $-14\sim-17$°C which is favorable for the development of the crystals to hexagonal plane type. Then the crystals rapidly grew to dendritic snow crystals by the condensation as observed at levels higher than 1000 m. The moisture supply comes from the supercooled cloud droplets.

As the snow crystals fall to warmer levels, the rate of crystal growth by condensation decreases, because at the warmer temperature region, the grade of supersaturation with respect to ice surface is small. At the lower levels of the cloud, the rate of growth by collision with cloud droplets was greater than that by condensation, in other words, riming of snow crystals occurred. This is why the snow crystals observed at Ishikari Plain were more or less rimed. As the cloud came inland, the supercooled cloud droplets were all swept clean, and only a light snowfall of slight riming was observed inland.

However it is not yet clear whether the graupel which was observed near the sea shore resulted from such riming in the lower cloud layer or from the anvil on the stratocumulus.

6. Conclusion

As a result of a detailed observation of snow clouds near the sea shore and of the distribution of snow crystals from the clouds it was ascertained that the local elongated snowfall area in the Ishikari Plain originated in a stratocumulus of band feature as pointed out by Higuchi and the snowfall near the coast was also affected by the orographic effect as pointed out by the Sapporo Meteorological Observatory. However, in the present large scaled observation complete data was obtained in only one case. Further problems concerning the effects of wind direction of the monsoon, the vertical structure of air during such a monsoon period, the cloud form and snowfall on the sea remain to be investigated. Since many detailed observations will be required for this, preparations for the next winter season are being made.

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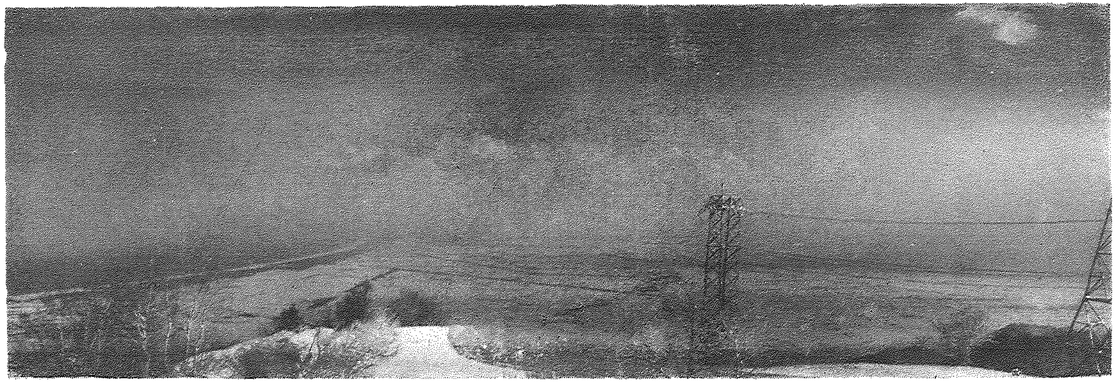
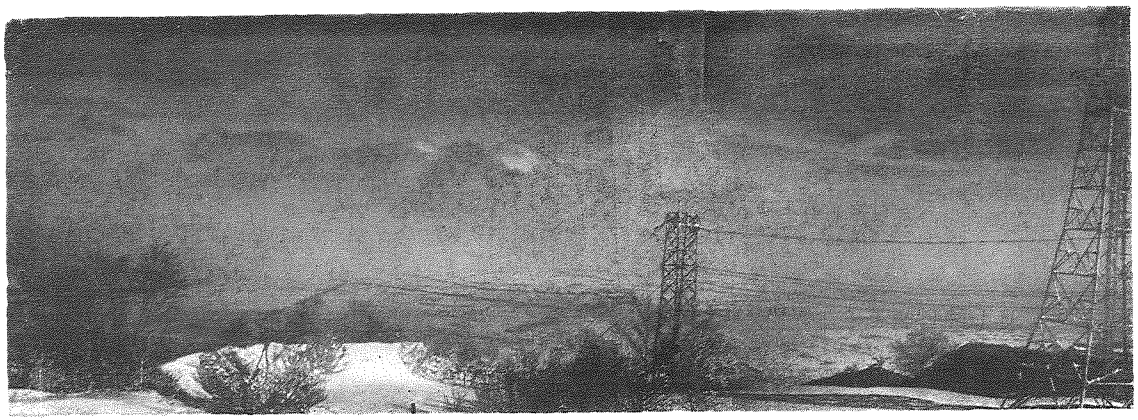
Pl. II Clouds over Ishikari Plain seen from Mt. Teine



NE

0837 16 Feb. Clouds of stratocumulus type come in from the Ishikari Bay and snowfall begins almost on the sea shore. The clouds are diffused as virga of flying snow crystals.

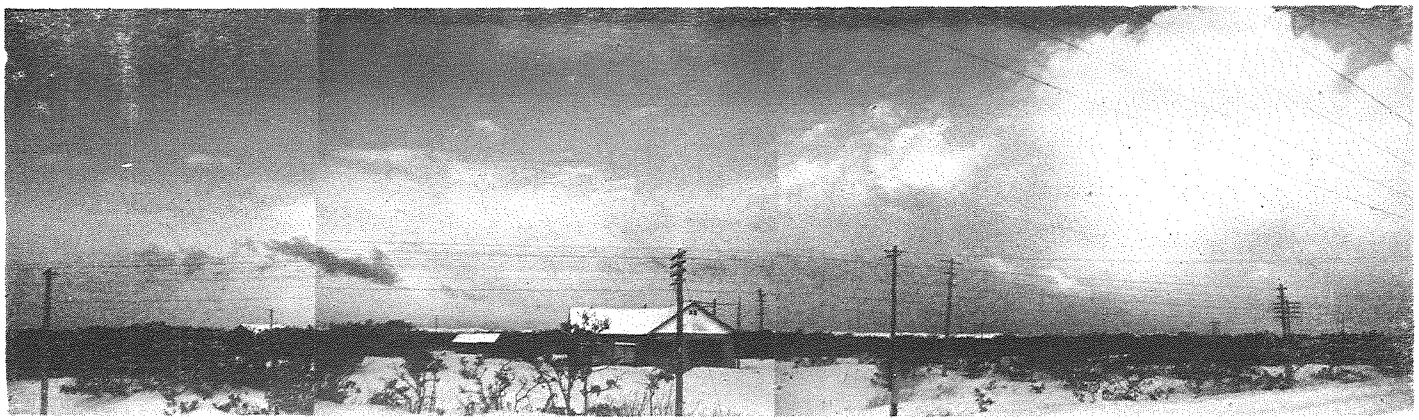


NE

0955 16 Feb. Cloud pattern is almost the same as above.

Pl. III Clouds around Ishikari

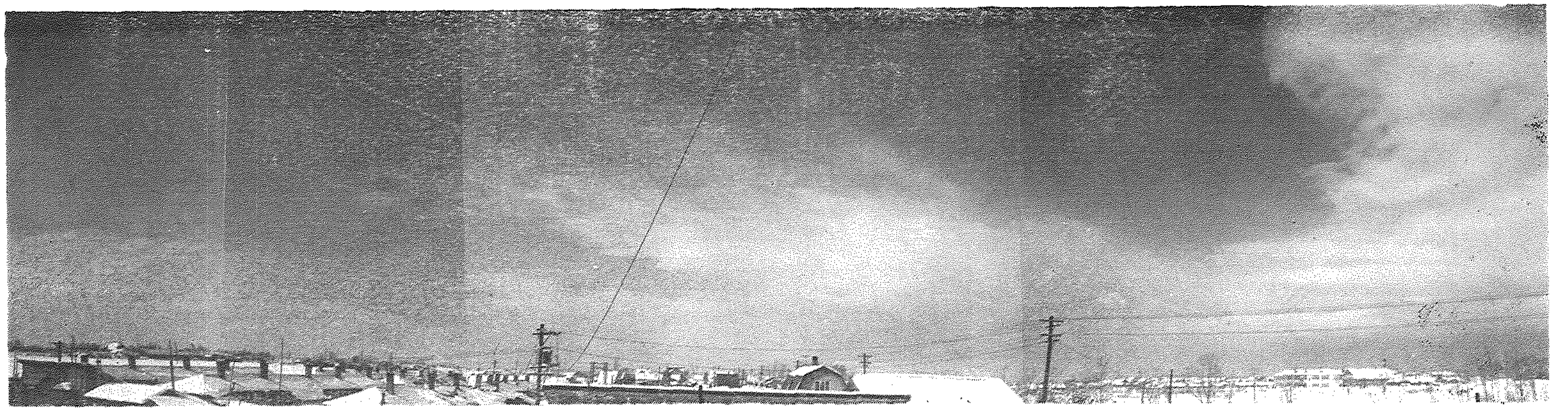
N E



W E

0810 16 Feb. Inland flow of stratocumulus clouds are seen to the east and to the west. The former corresponds to opposite side of the cloud in Pl. II.

Pl. IV Snow clouds around Tobetsu



S W N

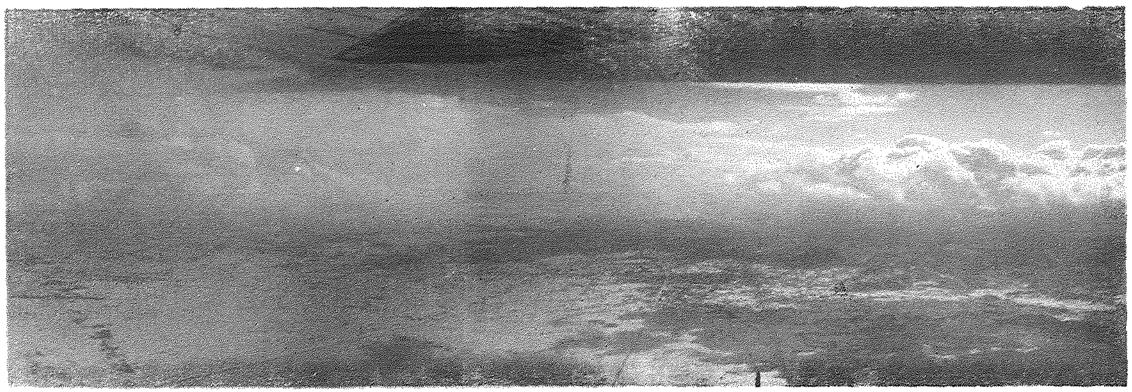
0950 16 Feb Three outflows of clouds from the north are seen. They were already glaciated and changed to virga.

Pl. V Clouds seen from aircraft

OTARU

WNW N

Clouds of anvil type are seen on stratocumulus.



SAPPORO SE

1059-1130 16 Feb. A clear area between Otaru and Sapporo is seen along the north-east end of Mt. Teine mountain area.