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Scientific Paper

ICE CRYSTALS OBSERVED AT CAMBRIDGE BAY AND INUVIK IN ARCTIC CANADA

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Abstract: Ice crystals in Arctic fog were observed at Cambridge Bay and Inuvik in the Northwest Territories, Canada. Not only prisms and hexagonal plates but also polyhedral crystals and crystals with hollows on $\{10\bar{1}1\}$ faces were found commonly in a dense ice fog at temperatures between –33 and –45°C. In a thin ice fog of about –30°C, trigonal plates and scalene hexagonal plates, ice crystals easily grown in a laboratory by a seeding technique, were observed.

1. Introduction

Long prisms, prisms, hexagonal plates and scalene hexagonal plates, ice single crystals which develop in very cold atmosphere above ground surface of polar regions, have been studied by THUMAN and ROBINSON (1954), KLINOV (1960), SHIMIZU (1963), OHTAKE (1970) and KIKUCHI and HOGAN (1979). However, growth conditions and growth mechanisms of these ice crystals are not always made clear, maybe because observations of ice crystals and laboratory experiments of ice crystal growth have been made independently.

In the present work, ice crystals grown in Arctic surface air were observed at Cambridge Bay (69°07′N, 105°03′W) from 15 January to 6 February 1994 and at Inuvik (68°21′N, 133°42′W) from 4 to 19 March 1995 in the Northwest Territories, Canada. Cambridge Bay is a hamlet on Victoria Island and Inuvik is a town about 100 km inland from the Beaufort Sea.

2. Surface Weather Situation during the Observation Periods and Observation Techniques

Data of airport surface weather stations at Cambridge Bay and Inuvik were useful. Our observation site at Cambridge Bay was about 5 km from the airport; Inuvik Research Centre, where we observed ice crystals at Inuvik, was at about 8 km from Inuvik Airport.

Cambridge Bay: Surface weather records at the airport are summarized in Fig. 1. Mean values of wind speed, air temperature and dew point of the observation period are 11.3 m/s, –33.8°C and –37.9°C, respectively. Data on obstructions to vision in the upper part of the figure show that thin diamond dust (ice crystals), dense diamond dust (ice fog), blowing snow crystals (blowing snow) and/or falling snow crystals (snowfall) were almost always found in the surface air. This weather situation seems to be attributable to the high wind speed close to the frozen sea. No clear diurnal variation of air temperature

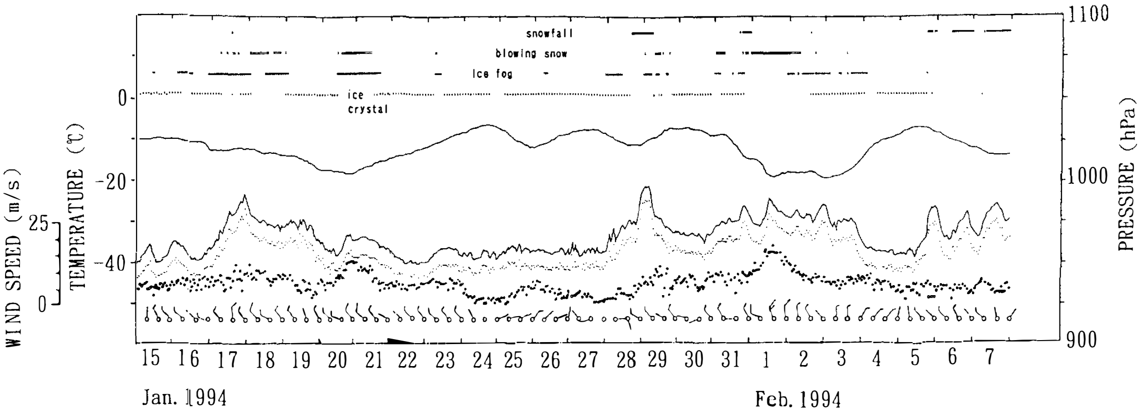

Fig. 1. Surface weather at Cambridge Bay Airport. Thick lines, double lines, broken lines and thin broken lines show the records of obstructions to vision of snowfall, blowing snow, ice fog and ice crystal, respectively. Curves (from the upper one to the lower one) show air pressure, air temperature, dew point, wind speed and wind direction.

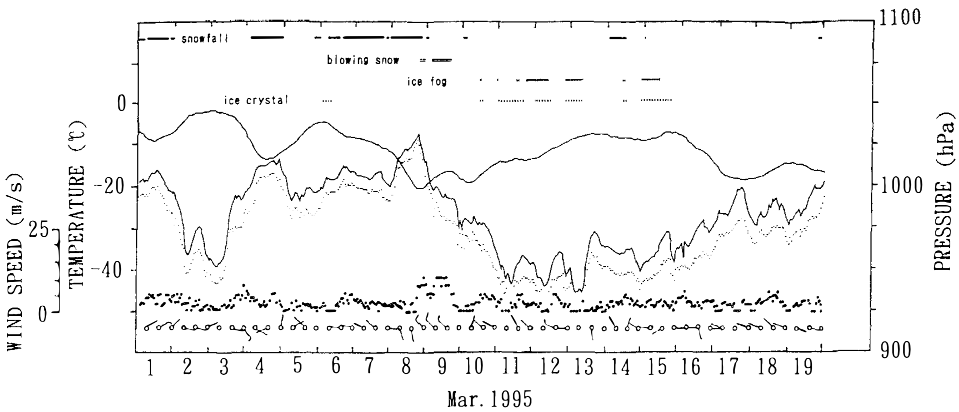

Fig. 2. Surface weather at Inuvik Airport (Lines and curves are the same as those in Fig. 1).

was found.

Inuvik: Surface weather records at the airport are summarized in Fig. 2. Mean values of wind speed, air temperature and dew point of the observation period are 4.6 m/s, –26.9°C and –33.1°C, respectively, and the lowest air temperature (–45.5°C) in the period was recorded at Inuvik on the morning of 13 March. The percentage of hours in which diamond dust was observed amounted only to 22% in the period; those of snowfall and no obstructions to vision were 28% and 44%, respectively. On clear days diurnal variation of air temperature was found and ice fogs were recorded early in the morning on 12, 13 and 15 March 1995.

Sampling and observation of ice crystals were carried out in the following way. A glass dish containing highly viscous silicone oil of 10000 c.s. is left on an outdoor stage as high as 1m for 0.5–10 min; fallen ice crystals are captured on the oil surface; a few sheets of thin cover glass are placed on sampled ice crystals; sampled crystals are observed and photographed under a polarization microscope in a cold room at about –15°C as soon as possible. Ice crystals were sampled several times a day normally, about three times per hour when snow crystals and/or ice crystals grown in the atmosphere were found. In the present study, ice crystals having facets were assumed to have been grown in air, for simplicity, and an atmospheric condition in which such ice crystals are found was defined as ice fog. When an ice fog developed at daytime optical phenomena such as sun dogs and/or sun pillars were always observed. At Cambridge Bay snow particles were observed drifting on the snow covered land surface frequently during the period. However, blowing snow crystals had rather rounded and irregular shapes and were easily judged to have not been grown in air.

3. Results

At Cambridge Bay four series of ice fog which developed at wind speed 4–7 m/s were observed and at Inuvik a very thin ice fog formed for a short time at night on 9 March when wind was very weak and dense ice fogs developed in the calm mornings on 12, 13 and 15 March were observed. Shapes of ice single crystals are classified, and their percentages and size ranges are shown in Table 1. Numbers of polycrystalline ice particles and ice fragments which have rounded shapes of blowing snow are also shown in the table. Typical photomicrographs of a prism and long prisms, a trigonal plate and scalene hexagonal plates (A and B) and those classified as polyhedral crystals are shown in Figs. 3, 4 and 5, respectively. Two typical examples of the observed ice fog are as follows:

A dense ice fog on 26 January 1994: Strong wind of about 10 m/s at night had calmed down, a dense ice fog developed at about –37.0°C and beautiful sun dogs were observed in the morning. Shapes of ice crystals were prisms (38%), polyhedral crystals and crystals with hollows on $\{10\bar{1}1\}$ faces (15%), scalene hexagonal plates (21%), hexagonal plates (21%), long prisms (6%) and a pentagonal plate (1%).Here, percentages are those of ice single crystals (68 crystals in total) grown in the air.

A thin ice fog on 9 March 1995: At daytime drifting snow particles were observed on snow covered surfaces at temperatures of about –20°C ~ –24°C and at wind speed of about 10 m/s. At night the strong wind stopped, air temperature began to fall rapidly and at about –29°C a thin ice fog developed at about 2130 LT and disappeared at about 2300 LT. Ice crystals grown in an early stage of this thin ice fog were found to have quite characteristic shapes: trigonal plates and scalene hexagonal plates of A-type which have been inferred to be grown from trigonal plates (Yamashita, 1973) amounted to 68% of ice single crystals (204 crystals in total) grown in the air, although sampled ice crystals were comparatively small.

Five other observations of ice fogs in the table represent results similar to that on 26 January 1994.

4. Discussion

Among the shapes of ice single crystals observed in the present study, long prisms, prisms, hexagonal and scalene hexagonal plates, trigonal plates and other plates have also been observed by Klinov (1960) and Kikuchi and Hogan (1979) and polyhedral crystals have been described by Ohtake (1970). It seems that ice crystals observed in the

Table 1. List of ice fogs observed at Cambridge Bay and Inuvik. The largest crystal size (the length along c-axis in the case of a prism) was measured, and the maximum and the minimum values of crystals are shown in the form (80–165 μm). Polyhedral crystals include ice crystals having one or more {10$\bar{1}$1} faces and those having hollows on {10$\bar{1}$1} faces.

	DATE	1994 (CAMBRIDGE BAY)				1995 (INUVIK)		
		26 JAN.	3~4 FEB.	4 FEB.	4~5 FEB.	9 MAR.	12 MAR.	13 MAR.
	HOUR (LST)	06:40~10:00	19:00~00:13	05:40~08:20	21:55~01:32	22:37~22:47	07:10~07:20	07:07~07:30
SURFACE WEATHER RECORD AT AIR PORT	Temperature (°C)*1	→ −37 →	↘ −33 ↘	→ −37 →	↘ −38 →	↘ −29 ↘	→ −44 ↗	→ −45 →
	Wind speed (m/s)*1	↘ 4~5 →	→ 7 →	↘ 6 →	→ 4 →	↘ 0.5 →	→ 0 →	→ 0 →
	Visibility (km)	3~12	3~5	24	19~24	24	5	10
	Sky Condition*2	clear	60sct(sc1-2)	60sct	clear	210sct(ci)	-x	clear
CONCENTRATION (%) AND SIZE (μm) OF ICE SINGLE CRYSTAL	Long prism*3	**6%** 80~165μm	**19%** 45~165μm	**16%** 75~400μm	**12%** 40~157μm	**2%** 192~320μm	**25%** 72~288μm	0% μm
	Prism	**38** 25~125	**65** 20~140	**33** 20~75	**39** 15~118	**5** 10~64	**12** 36~188	**40** 12~68
	Hexagonal thick plate*4	**13** 40~65	**3** 30~65	**4** 30~80	**8** 25~40	**7** 16~64	**2** 20	**15** 16~44
	Hexagonal plate	**6** 50~95	**2** 20~25	**3** 35~83	**8** 25~113	**2** 16~72	**10** 20~72	**15** 20~44
	Trigonal thick plate*4	0	0	0	0	**1** 20~56	0	0
	Trigonal plate	0	0	0	0	**27** 8~80	0	0
	Scalene hexa. plate A*5	**9** 45~120	**2** 20~100	**4** 35~90	**5** 25~78	**41** 12~100	**10** 52~80	**2** 20
	Scalene hexa. plate B*6	**12** 40~85	**5** 25~60	**21** 25~90	**9** 22~83	**11** 24~64	**33** 24~84	**17** 24~32
	Pentagonal, trapezoid etc	**1** 75	**2** 25~35	**1** 60	**1** 33	**3** 20~60	0	0
	Polyhedral	**15** 40~65	**2** 30~75	**18** 38~100	**18** 20~75	**1** 24~28	**8** 32~48	**11** 16~40
No. of single crystals		68	231	79	158	204	49	47
No. of poly-crystals & aggregates*7		57	100	33	3	58	63	50
No. of blowing ice crystals*8		83	801	81	424	84	131	378

*1 Arrows (↗, ↘ and →) show tendency of temperature or wind speed change comparing data of 2 hours before and after the observation period.
*2 60sct (sc1-2): cloud (sc) is scattered at 6,000ft level, -x: partially obscured, *3 c/a≧10 (C: length along c-axis, a:length in a-axis plane),
*4 1>c/a≧0.2, *5 plate with three shorter and three longer sides (see Fig.6 (c)), *6 plate not with three shorter and three longer sides,
*7 aggregates of ice crystals, poly-crystals and poly-crystal germs, *8 ice crystals which are inferred to be blown off from ground and evaporate a little in the air.

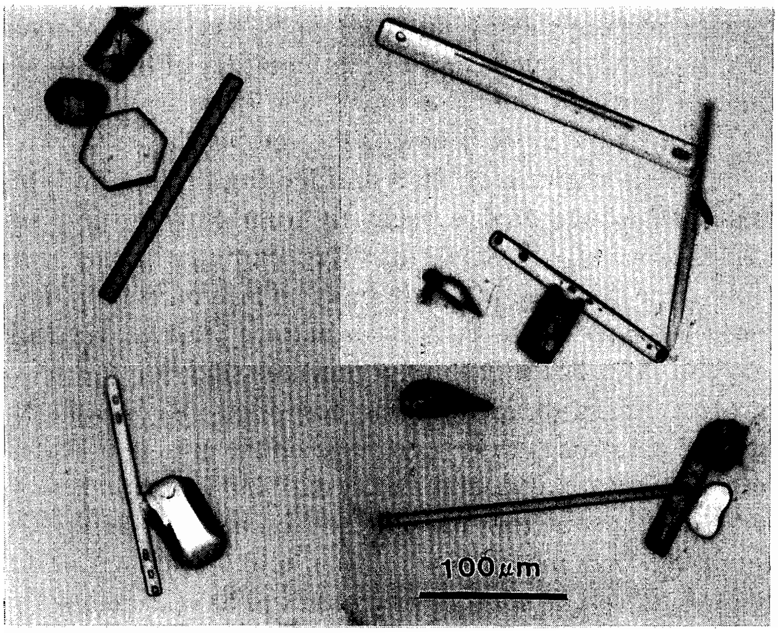

Fig. 3. Long prisms and a prism.

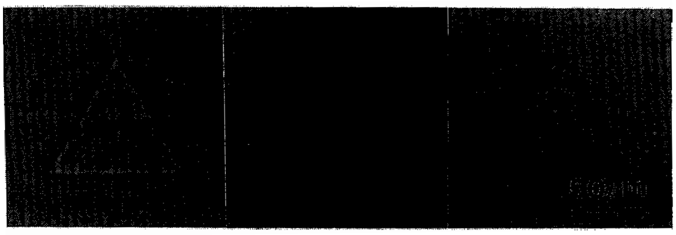

Fig. 4. (From left to right) A trigonal plate, a scalene hexagonal plate A (with three equal longer and three equal shorter sides) and a scalene hexagonal plate B (not with three equal longer and three equal shorter sides) observed on 9 March 1995.

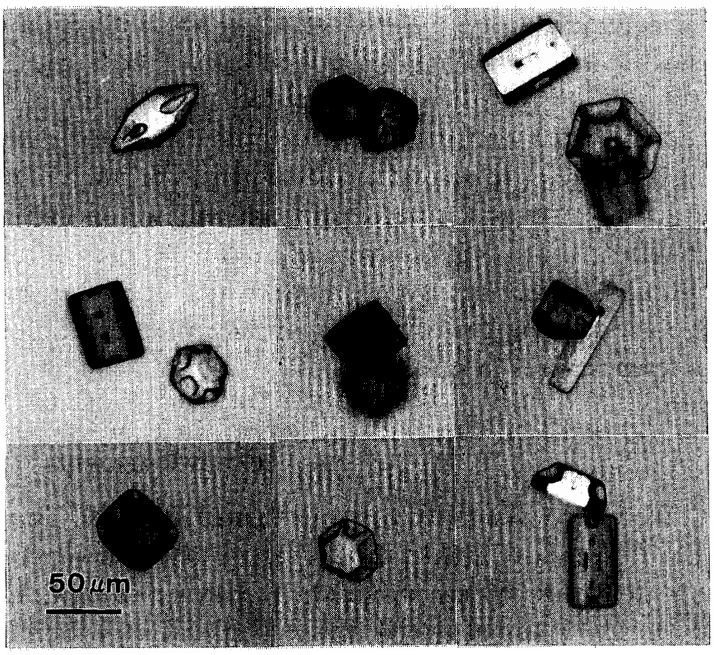

Fig. 5. Polyhedral crystals (ice crystals having one or plural {$10\bar{1}1$} faces and those having hollows on {$10\bar{1}1$} faces).

present work are almost the same types of crystals observed in Siberian ice fogs (KLINOV, 1960) on the whole because great numbers of blowing snow particles and polycrystalline ice particles were also found (see Table 1).

Polyhedral crystals having the various shapes shown in Fig. 5 were found at a relatively high ratio except in a thin ice fog formed on 9 March 1995. As blowing snow particles are supplied ceaselessly from snow covered surfaces by human activity and wind, especially at Cambridge Bay, particles having rather rounded shapes may probably grow in the air in conditions in which an ice fog develops. Growth mechanisms of observed polyhedral ice crystals and ice crystals with hollows on $\{10\bar{1}1\}$ faces are not easy to infer because an experimental study on the growth of spherical frozen water droplets (YAMASHITA, 1974) has described only initial stages of their growth and no experimental studies have been made on the growth of distorted spherical particles. However, observed polyhedral ice crystals and ice crystals with hollows on $\{10\bar{1}1\}$ faces are probably grown from blowing snow particles having rounded shapes because the assumption that spherical ice single crystals and distorted spherical ice single crystals grow similarly to some degree seems to be reasonable.

Trigonal plates and scalene hexagonal plates having three equal longer and three equal shorter sides, which were sampled in a thin ice fog on 9 March 1995 at very high ratios of 27% and 41% of ice single crystals, respectively, suggest the effect of nucleation at comparatively low temperatures on the shapes and growth mechanisms of ice crystals; YAMASHITA (1973) has shown that these ice crystals commonly grow over wide temperature ranges by seeding techniques including expansion cooling. Since KIKUCHI and HOGAN (1979) have also described the case in which these plates were found at a high ratio at South Pole Station, Antarctica, further experimental studies and analysis of observed data will be indispensable for further study.

5. Conclusions

Ice crystals in ice fogs formed in Arctic Canada were observed at two different places. It was found that ice crystals in Arctic fogs which developed at temperatures about −29°C ~ −45°C were composed of single crystals and polycrystals grown in the air and blowing ice particles having rather rounded shapes. Although ice single crystals were found to have almost the same shapes found in the previous observations, polyhedral ice crystals and ice crystals with hollows on $\{10\bar{1}1\}$ faces which were found at a high ratio in the present study were presumably grown from blowing ice particles. Trigonal plates and scalene hexagonal plates, which occupied about 68% of ice single crystals in a thin ice fog, suggested the importance of nucleation on the growth of ice crystals at low temperatures in polar regions.

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References

KIKUCHI, K. and HOGAN, A.W. (1979): Properties of diamond dust type ice crystals observed in summer season at Amundsen-Scott South Pole Station, Antarctica. J. Meteorol. Soc. Jpn., **57**, 180–190.

KLINOV, F. JA (1960): Voda v Atmosphere pri Nizkikh Temperaturakh. Acad. Sci. USSR, 171 p.

OHTAKE, T. (1970): Unusual crystal in ice fog. J. Atmos. Sci., **27**, 509–511.

SHIMIZU, H. (1963): "Long Prism" crystals observed in precipitation in Antarctica. J. Meteorol. Soc. Jpn., **41**, 305–307.

THUMAN, W.C. and ROBINSON, E. (1954): Studies of Alaskan ice fog particles. J. Meteorol., **11**, 151–156.

YAMASHITA, A. (1973): On the trigonal growth of ice crystals. J. Meteorol. Soc. Jpn., **51**, 307–317.

YAMASHITA, A. (1974): Experimental study of ice crystals by a large cloud chamber. Kishô Kenkyû Nôto (Meteorol. Res. Note), **123**, 813–860 (in Japanese).

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