

Correspondence

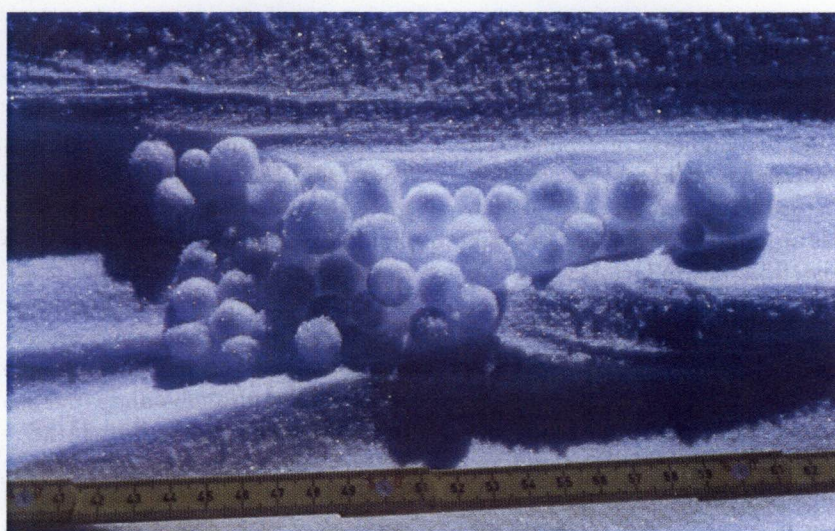
The Editor,
Journal of Glaciology

SIR,

Observation of "yukimarimo" on the snow surface of the inland plateau, Antarctic ice sheet

Many small balls were observed on the surface of the ice sheet at Dome Fuji station (77°19'01"S, 39°42'12"E; 3810 m a.s.l.), located at the highest point in Dronning Maud Land, Antarctica, during the first overwintering of the Japanese Antarctic Research Expedition (JARE) in 1995.

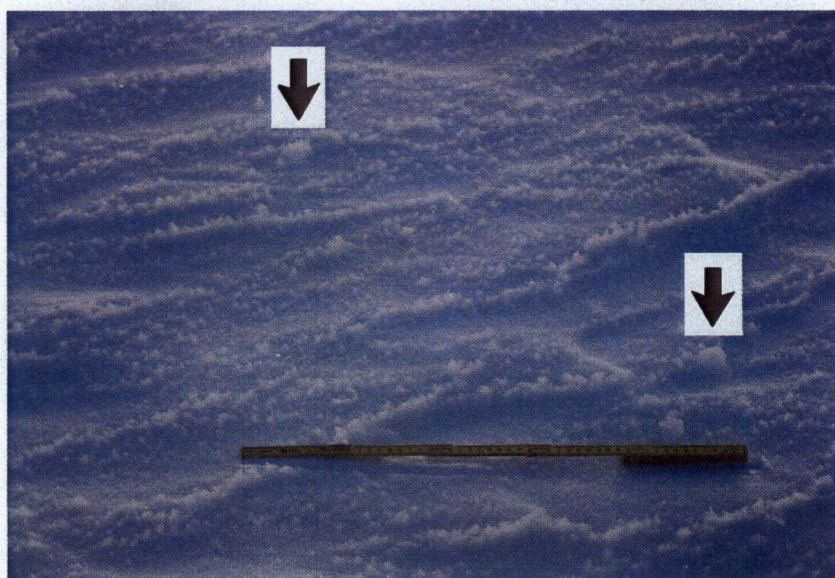
Solid-needle-type (SN) surface hoar crystals formed the balls. Figure 1 shows a cluster of the balls; their diameters range from 5 to 30 mm. They were naturally collected by wind. They look quite similar to globular marimo plants (*Cladophora sauteri* Kützing; Sakai, 1964) which are observed in Lake Akan in Hokkaido, Japan. Thus, we named them "yukimarimo" ("yuki" means snow in Japanese). They were fragile, but did not break apart when handled carefully. The average density of yukimarimo was about 50 kg m^{-3} . The photograph in Figure 1 was taken at 1100 h on 26 October 1995, and that in Figure 2 the day before (0900 h on 25 October) at the same location. SN surface hoar crystals were growing on the snow surface, and some crystals were already



10 cm



Fig. 1. "Yukimarimo" on the snow surface at Dome Fuji station, Antarctica.



30 cm



Fig. 2. SN surface hoar crystals and yukimarimo on the snow surface.

formed into lumps of SN surface hoar crystals and yukimarimo, as indicated by arrows. Figure 3 shows the microscopic photograph of the SN surface hoar crystals. The mean diameter and the length of the needle crystals are about 0.01 and 1 mm, respectively. The shape is different from commonly observed "feathery and flat" surface hoar crystals (Lang and others, 1984; Colbeck, 1988; Colbeck and others, 1990), but is similar to "solid needle" snow crystals (Shimizu, 1964) which were observed at -50.0°C at Byrd Station, Antarctica.

Similar descriptions of yukimarimo were briefly reported by Amundsen (1912, p. 389) and Siple (1959, p. 290). Roald Amundsen observed "cylindrical bodies of drift snow" on the snow surface during his first traverse on the Ross Ice Shelf, Antarctica, in September 1911. He wrote that "Fine, extremely fine, drift-snow collected, and formed small cylindrical bodies of an average diameter of $1\frac{1}{4}$ inches, and about same height; they were, however, of various sizes". Paul A. Siple wrote that "Some days the Met men saw 'snow down', wispy balls of frost one to two inches in diameter, but so delicate that the slightest touch caused them to collapse into nothing". This observation was made during the first overwintering at Amundsen-Scott station at South Pole in 1957. The descriptions by the two authors correspond well with our observations. However, we could find no other information on this subject in the literature.

Snow surface conditions around Dome Fuji station were examined at least once a day from July to October 1995. We observed yukimarimo and SN surface hoar crystals six times, and the SN surface hoar crystals alone twice. They survived 1-3 days on the snow surface. When the wind was strong, they disappeared.

Air and surface-snow temperature changes during the formation of yukimarimo and SN surface hoar crystals are shown in Figure 4. Air temperature was measured at 1.5 m height (Japan Meteorological Agency, 1996), and surface snow temperature at 0.01 m depth (Kameda and others, 1997b). We did not notice any yukimarimo and SN surface

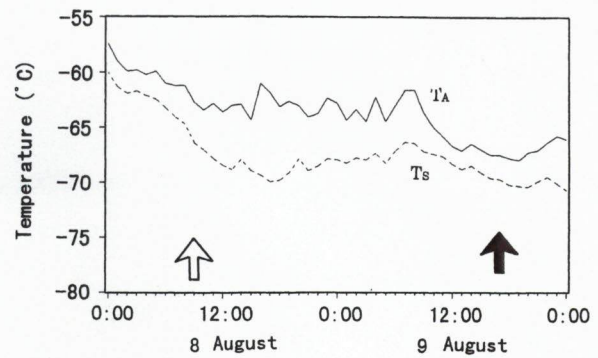
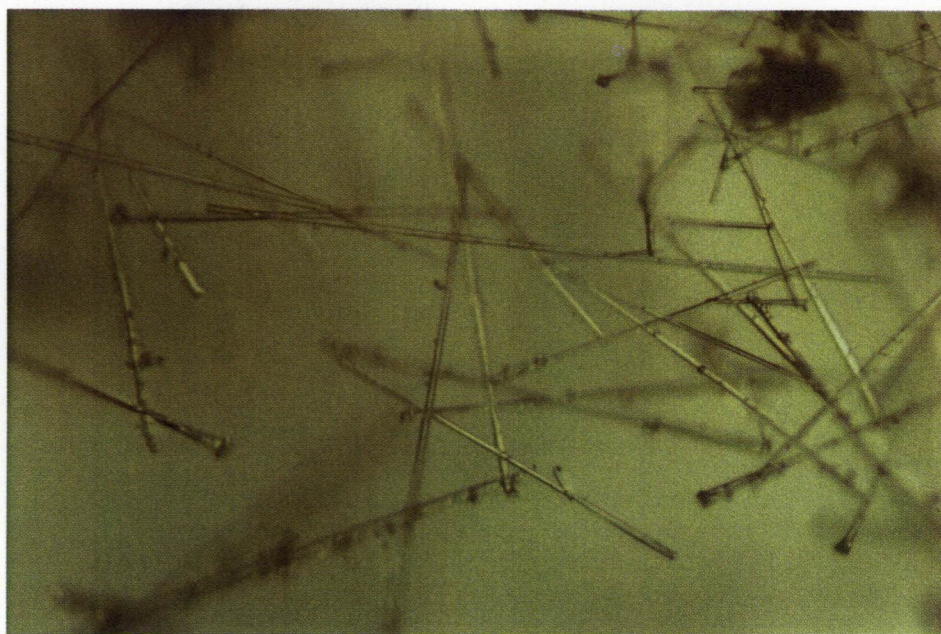


Fig. 4. Air and surface snow temperatures during the formation of yukimarimo, 8-9 August 1995. Yukimarimo and SN surface hoar crystals on the snow surface were not observed at the time marked by the open arrows, but were observed at the moment indicated by the solid arrow.

hoar crystals on the snow surface at the time marked by the open arrow, but we observed yukimarimo and SN surface hoar crystals at the moment indicated by the solid arrow. Thus, they were formed during the period between the two arrows. Air temperature during the formation period varied from -60.3° to -68.2°C , and surface snow temperature from -66.3° to -69.8°C . Because the surface snow was cooled by radiation, water vapor in the air near the surface should have condensed and formed SN surface hoar crystals on the snow surface.

Table 1 summarizes meteorological conditions during the formation of yukimarimo and SN surface hoar crystals for all observations in 1995: air temperature (T_A), surface snow temperature (T_S) and wind velocity (V). Maximum and minimum values during the formation period are shown in T_A , T_S and V . Wind velocity was measured at 2.2 m height (Kameda and others, 1997a). The average thickness of SN surface hoar crystals at the end of the formation period was measured on the snow surface, and at 0.8 and 1.3 m above the snow surface on two bamboo poles.



1 mm

Fig. 3. SN surface hoar crystals.

Table 1. Meteorological conditions when yukimarimo and SN surface hoar crystals were observed at Dome Fuji station in 1995

Formation period	T_A	T_S	V	Average length of SN surface hoar crystals at end of formation period			Yukimarimo	SN surface hoar crystals
				Snow surface	0.8 m height	1.3 m height		
				°C	°C	$m s^{-1}$		
1700 h, 28 July to 1700 h, 29 July	-38.2 to -52.2	-40.6 to -54.8	1.2-11.7	-	-	-	Yes	Yes
0900 h, 8 Aug. to 1700 h, 9 Aug.	-60.3 to -68.2	-66.3 to -69.8	0.5-3.8	10	15	17	Yes	Yes
1100 h, 18 Aug. to 1100 h, 19 Aug.	-63.1 to -79.6	-77.1 to -80.9	0.5-3.5	2	3	5	Yes	Yes
0900 h, 23 Aug. to 0900 h, 24 Aug.	-67.2 to -75.0	-71.6 to -77.6	0.5-2.8	2	3	3	No	Yes
1145 h, 10 Sept. to 1100 h, 11 Sept.	-59.3 to -68.4	-64.1 to -70.3	1.6-4.2	5	8	8	Yes	Yes
0900 h, 21 Sept. to 0900 h, 22 Sept.	-60.6 to -75.0	-68.2 to -78.1	0.5-3.5	2	3	3	Yes	Yes
1100 h, 26 Sept. to 1100 h, 27 Sept.	-64.7 to -71.9	-67.5 to -71.6	1.5-3.0	5	10	10	No	Yes
0900 h, 24 Oct. to 0900 h, 25 Oct.	-38.4 to -52.3	-45.8 to -54.0	2.1-5.0	2	3	3	Yes	Yes

Yukimarimo and the SN surface hoar crystals were observed when air temperature ranged from -38.2° to -79.6°C , surface snow temperature from -40.6° to -80.9°C and wind velocity from 0.5 to $11.7 m s^{-1}$. Yukimarimo was found when maximum wind velocity was $>3.0 m s^{-1}$. Thick layers of SN surface hoar crystals were observed on 9 August, 11 September and 27 September when air temperature ranged from -59.3° to -71.9°C , surface snow temperature from -64.1° to -71.6°C and wind velocity from 0.5 to $4.2 m s^{-1}$. It seems that these values delimit the most favorable conditions for the growth of SN surface hoar crystals.

If the thickness of the SN surface hoar crystal layer was growing at a constant rate during the formation period in Table 1, the thickness growth rate ranged from 0.08 to $0.3 mm h^{-1}$ at the snow surface. The smallest rate was observed when the surface snow temperatures were lower (19 and 24 August, 22 September) or higher (25 October) than those delimiting the most favorable conditions.

We conclude that air temperature from -59.3° to -71.9°C , surface snow temperature from -64.1° to -71.6°C and wind velocity from 0.5 to $4.2 m s^{-1}$ are the most favorable conditions for the growth of SN surface hoar crystals on the snow surface. In addition, when wind velocity is $>3.0 m s^{-1}$, some of the SN surface hoar crystals will rotate on the snow surface and form yukimarimo.

ACKNOWLEDGEMENTS

We would like to express our sincere thanks to JARE-36 members. E. Akitaya, M. Hachikubo and I. Wakana kindly referred us to some of the literature cited in this letter. The authors are indebted to S. Takahashi for valuable discussions. Comments from an anonymous reviewer are gratefully acknowledged. This letter is a contribution from the "Deep Ice Coring Project at Dome Fuji Station, East Antarctica" (principal investigator: O. Watanabe).

Kitami Institute of Technology,
165 Koencho, Kitami,
Hokkaido 090, Japan

T. KAMEDA

Japan Meteorological Agency,
Ootemachi, Chiyoda-ku,
Tokyo 100, Japan

H. YOSHIMI

Nagaoka University of Technology,
1630-1 Kamitomiokacho,
Nagaoka, Niigata 940-21, Japan

N. AZUMA

National Institute of Polar Research,
Kaga 1-9-10, Itabashi-ku,
Tokyo 173, Japan

H. MOTOYAMA

26 January 1999

REFERENCES

- Amundsen, R. 1912. *The South Pole. An account of the Norwegian Antarctic Expedition in the "Fram", 1910-1912.* Translated from the Norwegian by A. G. Chater. London, John Murray.
- Colbeck, S. C. 1988. On the micrometeorology of surface hoar growth on snow in mountainous area. *Boundary-Layer Meteorol.*, **44**(1-2), 1-12.
- Colbeck, S. C. and 7 others. 1990. *The international classification for seasonal snow on the ground.* Wallingford, Oxon, International Association of Scientific Hydrology. International Commission on Snow and Ice.
- Japan Meteorological Agency. 1996. *Meteorological data at Syowa Station and Dome Fuji Station in 1995.* Tokyo, Japan Meteorological Agency. (Antarctic Meteorological Data 36.)
- Kameda, T. and 9 others. 1997a. Meteorological observations along a traverse route from coast to Dome Fuji Station, Antarctica, recorded by automatic weather stations in 1995. *Proc. NIPR Symp. Polar Meteorol. Glaciol.* **11**, 35-50.
- Kameda, T., N. Azuma, T. Furukawa, Y. Ageta and S. Takahashi. 1997b. Surface mass balance, sublimation and snow temperatures at Dome Fuji Station, Antarctica, in 1995. *Proc. NIPR Symp. Polar Meteorol. Glaciol.* **11**, 24-34.
- Lang, R. M., B. R. Leo and R. L. Brown. 1984. Observations on the growth process and strength characteristics of surface hoar. In *ISSW84. A merging of theory and practice. International Snow Science Workshop, 24-27 October 1984, Aspen, Colorado. Proceedings.* Aspen, CO, ISSW Workshop Committee, 188-195.
- Sakai, Y. 1964. *The species of Cladophora from Japan and its vicinity.* Sapporo, Hokkaido University. Faculty of Science. Institute of Algological Research. (Sci. Pap. V(1).)
- Shimizu, H. 1964. Glaciological studies in West Antarctica, 1960-62. In Mellor, M., ed. *Antarctic snow and ice studies.* Washington, DC, American Geophysical Union, 37-64. (Antarctic Research Series 2.)
- Siple, P. A. 1959. *90° South. The story of the American South Pole conquest.* New York, G. P. Putnam's Sons.



VOLUME 45 1999 NUMBER 150

JOURNAL OF GLACIOLOGY

Published by the International Glaciological Society, Cambridge, England

