QUICK GROWTH OF DEPTH HOAR IN A SURFACE LAYER

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ABSTRACT

The quick growth of a weak layer of depth hoar in a surface layer was observed on a mountain slope in northern Hokkaido, Japan.

When the weather becomes clear after the deposition of a thin (less than 3cm) new snow layer on denser and older snow, the temperature of the dense snow rises under calm sunny weather by the absorption of solar radiation in the day time. After sunset the surface temperature of new snow drops rapidly by radiative cooling and a large temperature gradient (2° C/cm) appears in the new snow, just beneath the surface. It was determined that such a large temperature gradient overnight resulted in the quick growth of depth hoar at the new snow surface layer.

INTRODUCTION

A weak layer existing in a snow cover, called a sliding surface, plays an important role in a slab avalanche release. So it is important to know the process of formation of weak layers for avalanche forecasting. Faceted crystals (i.e. depth hoar) are known to compose a typical weak layer in snow cover. These crystals have long been observed near the bottom of snow cover(Akitaya, 1974). However, depth hoar has also been observed in the layers near the surface (Seligman, 1934, p.70; Armstrong, 1981; Akitaya and Simizu, 1987). High growth rates of depth hoar crystals just below the surface were calculated by Colbeck (1989).

To examine how long it takes to change new snow crystals to faceted crystals, we observed the snow metamorphism near the surface, measuring temperature of snow and air, radiation, and wind speed on a south-facing mountain slope near our avalanche research station (240m a.s.l.) in Toikanbetu, Northern Hokkaido, for 50 days in winter of 1989-1990.

OBSERVATIONS

Measurements of snow temperatures were made, using thermocouples every 2cm from the surface to 8cm depth and at 10 minute intervals during night time. The measurement device is shown schematically in figure 1. Snow crystals from 1cm depth were sampled and microscopic photographs of these crystals, scattered on a glass, were taken at the times of sunset and sunrise, and often at other times in the night.

Air temperature was measured at 1.0m above the snow surface. Net radiation of all wavelengths and solar radiation were measured at the height of 0.9m and 0.52m, respectively, with an all

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wavelength net radiometer and a pyranometer.Wind velocity was measured at 1.5m with a 3-cup anemometer.

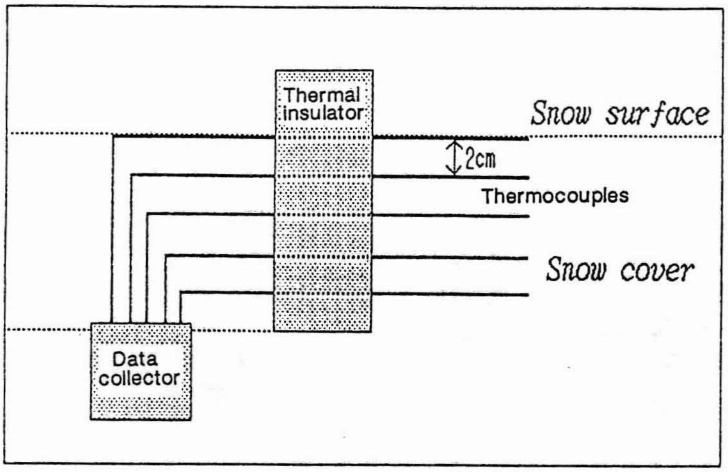

Fig. 1. A device for measurement of snow temperature.

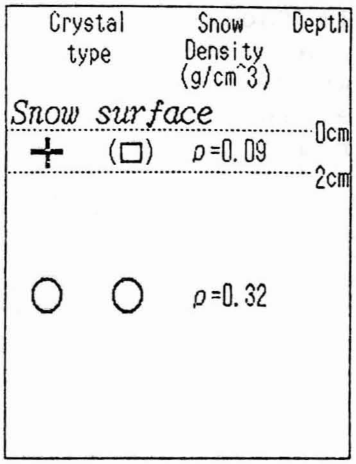

Fig. 2. Snow stratigraphy at sunset of 2 March, 1990.

RESULTS

Snow stratigraphy at sunset(16:30) of 2 March, 1990 is shown in figure 2. There was 2cm of new snow on the older wet granular snow. Snow densities were 0.09 and 0.32g/cm^3, respectively.

The snow temperature profile during the night time of 2-3 March is shown in figure 3. A large temperature gradient can be seen in the layer near the surface. Particularly, in the new snow layer just beneath the surface to 2cm depth, very large temperature gradient of 2°C/cm can be seen persisting for 14 hours through the night.

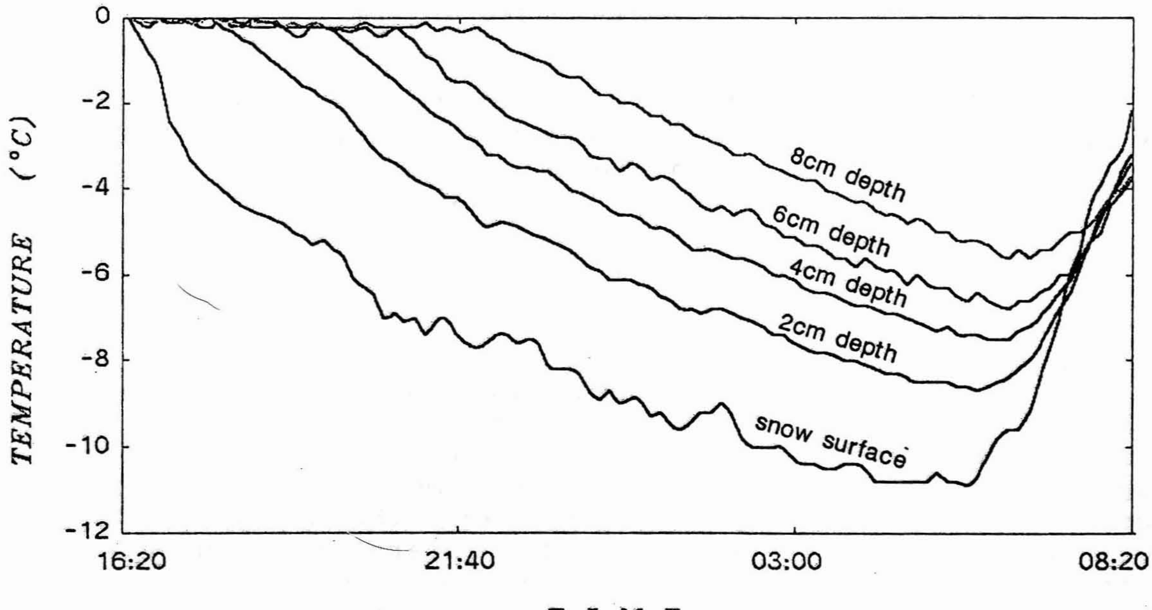

Fig. 3. Snow temperature profile at every 2cm from surface to 8cm depth during the night time of 2-3 March,1990.

Microscopic photographs of snow crystals from 1cm depth at the times of sunset and sunrise are given in figure 4a and 4b, respectively. Figure 4a shows new snow crystals along with a few small faceted crystals. Following Armstrong (1981), these faceted crystals are thought to have grown during day time. Figure 4b shows depth hoar crystals and faceted crystals of about 1mm in size. Thus, it is clear that the new snow layer changed to depth hoar during the night.

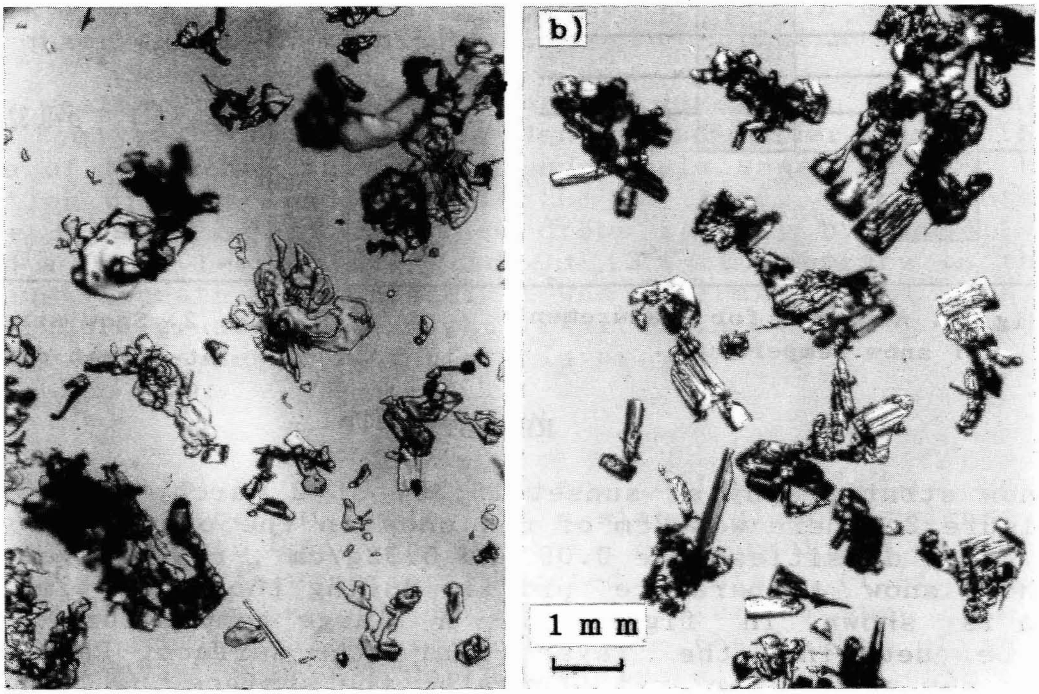

Fig. 4. Microscopic photographs of snow crystals sampled from 1cm depth at 16:20(a) of 2 March and 6:30(b) of 3 March, 1990.
a) New snow crystals along with a few small faceted crystals.
b) Depth hoar crystals of about 1mm in size.

The weather of 2-3 March was that fine weather persisted in day time and radiative cooling was high after evening. Accordingly, surface temperature decreased rapidly. Wind was very calm all day, averaging 0.8m/sec in velocity.

DISCUSSION

In figure 3, internal melting can be seen below the surface for several hours after sunset, influenced by a diurnal solar radiation (Yosida, 1960), while the snow surface temperature decreased rapidly, influenced by radiative cooling. Internal snow temperatures remained at 0°C until melt water refroze, then decreased by heat conduction. However, thermal conductivity of new snow is small, therefore, large temperature gradient persisted in the thin new snow layer during the night time. Thus, it is considered that quick growth of depth hoar in the surface layer took place in this period.

The quick growth of depth hoar in the surface layer described above was observed 10 times out of 50 days during the observation period. In all case, new snow metamorphosed to depth hoar during one or two night. This quick growth could be observed more in March than in January because March has more clear days with grater solar radiation, so internal melting can take place more often.

CONCLUSION

The profile of snow temperatures and microscopic photographs showed that depth hoar crystals were produced over a night in the surface layer under these conditions, shown schematically in figure 5.

The first condition is a stratigraphy in which a low density layer of several centimeters overlays on a denser snow layer in the south-facing slope.

The second condition is an internal temperature increasing within a snow cover due to diurnal solar radiation. If internal melting takes place, it increases the temperature gradient, hence promoting growth of depth hoar.

The third condition is surface temperature decreasing due to radiative cooling in calm and clear weather during the night.

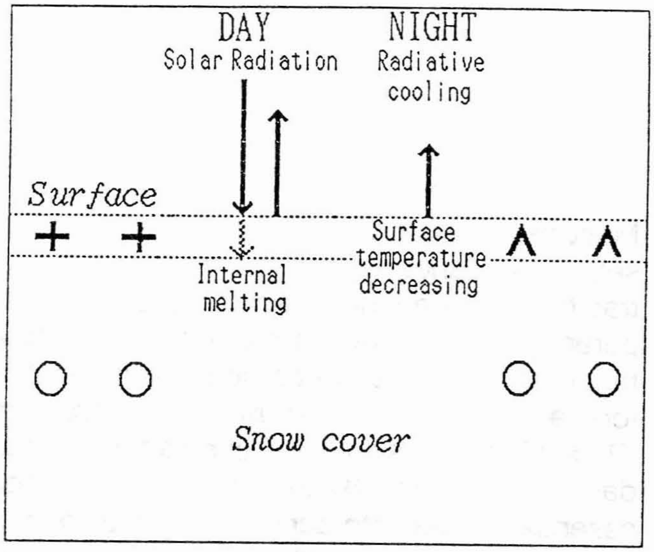

Fig. 5. Schematic diagram for mechanism of quick growth of depth hoar in a surface layer.

In northern Hokkaido, these conditions are more common in late winter than in mid winter. When such conditions are present, the quick growth of depth hoar takes place in the surface layer of low density snow.

REFERENCES

Akitaya, E. and Shimizu, H. 1987. Observations of weak layers in a snow cover. Low Temp. Sci., Ser. A, 46, 67-75.

Akitaya, E. 1974. Study on depth hoar. Contr. Inst. Low Temp. Sci., A, 26, 67pp

Armstrong, R. L. 1981. Snow observations on snowcover temperature patterns. Proc. Avalanche Workshop 3-5 November 1980 Vancouver, B.C.

Colbeck, S. C. 1989. Snow-crystal growth with varying surface temperatures and radiation penetration. J. Glaciol., Vol. 35, No. 119.

Seligman, G. 1936. Snow structure and ski field. McMillan and Co., Ltd. London.

Yosida, Z. 1960, Internal melting of snow due to the penetrating sunlight. Low Temp. Sci., Ser. A, 19.