Proc. NIPR Symp. Polar Meteorol. Glaciol., 2, 161–168, 1989

UNUSUAL RETREAT AND ADVANCE OF POLAR AIR MASS OVER MT. CHOKAI BASED ON 8000-HOUR TEMPERATURE RECORDS BENEATH THE VERY DEEP SNOW COVER FROM TWO MEMORY-TYPE THERMOMETERS DURING 1986/87

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Abstract: Before the snowfall season of 1986, two high-resolution memory-type thermometers were placed at a location in the snow patch vegetation zone in Mt. Chokai, Japan. They were collected after the snow-melting in summer of 1987 to obtain the temperature records of bottom snow and sub-surface ground beneath the very deep snow cover. In the two series of temperature records for 8000 hours, an abrupt change of temperature was recognized as an influence of a stormy warm weather event called "Haru (spring) Ichiban (the first time)". These two thermometers have recorded the indications of an unusual retreat and advance of polar air mass beneath the deep snow of ten or more meters during the late winter season. A transient heat transfer by snow-melt water due to an unusual warm event is a major factor in the abrupt snow temperature change.

1. Introduction

One of the remarkable features of winter in Japan is the heavy snowfall along the coast of the Japan Sea. Very cold polar air mass over eastern Siberia which was generated in Arctic regions comes in contact with the mountatin ranges of the axis of Honshu. An extraordinarily large amount of snow falls on these windward mountain ranges due to the massive moisture transfer from warm waters of the Japan Sea. The snow cover depth exceeds ten-odd meters or more at many leeward slopes in these windward mountain ranges (TSUCHIYA, 1984).

Daily or hourly temperature records of such deep snow cover during one winter season would be very useful for management of the water resources and the conservation of the natural environment of the mountain area; they could also provide an understanding of the interaction between the polar air mass and the mountain snow cover. However, long-period thermometry of mountain snow cover is very difficult, and there are few observational reports except for short-period or interval observations in snowy mountains (*e.g.*, NAKAGAWA *et al.*, 1976).

Recently a new memory-type thermometer was developed. It accumulates temperature data in IC memory; thereby it is possible to measure daily or hourly temperature of snow cover regardless of the usual difficulties related to deep snow and dangerous stormy weather.

Clear evidence of a retreat and advance of polar air mass which affects the thermal structure of deep snow cover was considered in the temperature records obtained by these thermometers in bottom snow and sub-surface ground in the transitional period from winter to spring beneath ten-odd meters of snow during 1986/87 on Mt. Chokai, Japan.

In this paper some preliminary analyses of that evidence from temperature records and some related phenomena are presented.

2. Observation

On September 19, 1986, two RMT (Rigo-sha Memory Thermometer) were placed at the western slope of the cirque where there is a small ice body called Kaigata Glacieret. The altitude of the slope is about 1450 m a.s.l. and the observation site of the slope is covered with snow patch vegetation as shown in Fig. 1. Table 1 shows the specification of the RMT thermometer.

A sensor probe of one RMT thermometer was installed about 3 cm above the ground surface to measure the temperature of the bottom of the snow cover during the continuous-snow-cover period or the near ground surface air during the no-snow-cover period. And a sensor probe of another RMT thermometer was set about

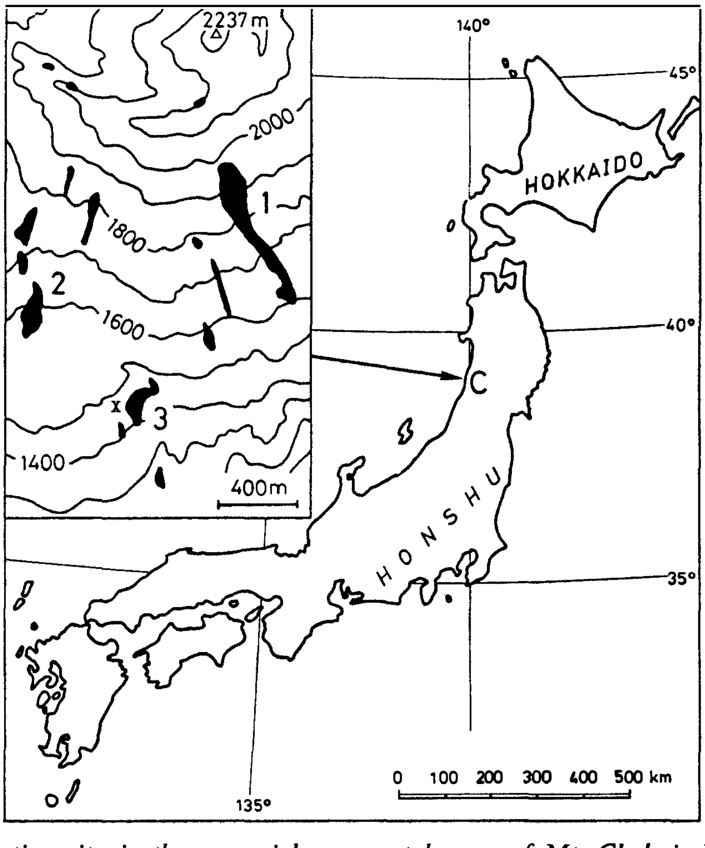

Fig. 1. Observation site in the perennial snow patch zone of Mt. Chokai, Japan. C: Mt. Chokai, X: observation site and a part of the snow patch vegetation zone, 3: Kaigata Glacieret, 1, 2, and 3: may be niche glacier.

Table 1. Instrument specification of RMT thermometer (Rigo-sha Ltd.).

Sensor	Platinum resistance bulb
Range	−5 to +50°C
Resolution	0.02°C
Accuracy	±0.05°C
Memory	4000 data
Interval	1 to 127 minutes
Weight	550 g

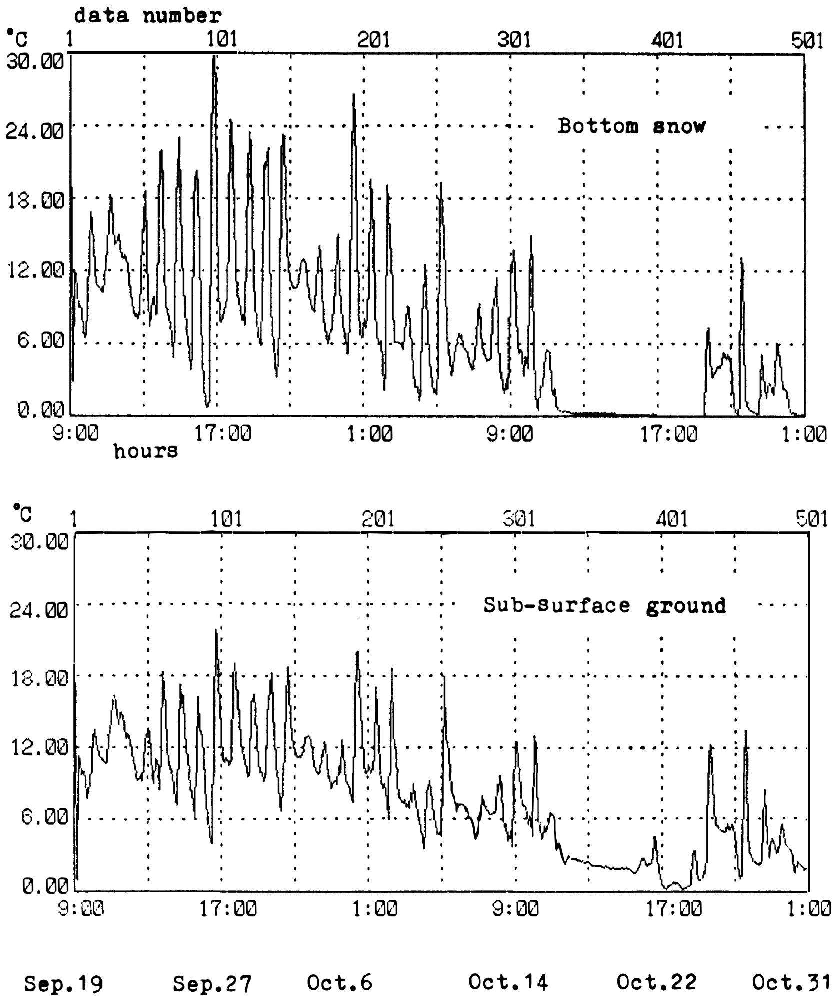

Fig. 2. Temperature of bottom snow and sub-surface ground during placement of two RMT thermometers and following days in autumn, 1986.

3 cm beneath the ground surface to measure the temperature of the sub-surface of the ground. Sites of the two RMT thermometers were nearly one meter away from each other. During the period from September 19, 1986, to August 18, 1987, automated temperature observations were continued 12 times per day.

After the placement of the two RMT thermometers, almost-no-snow days continued for about one month, although a cold wave brought a transient snow cover in mid-October, and the date of the beginning of complete continuous-snow-cover dura-

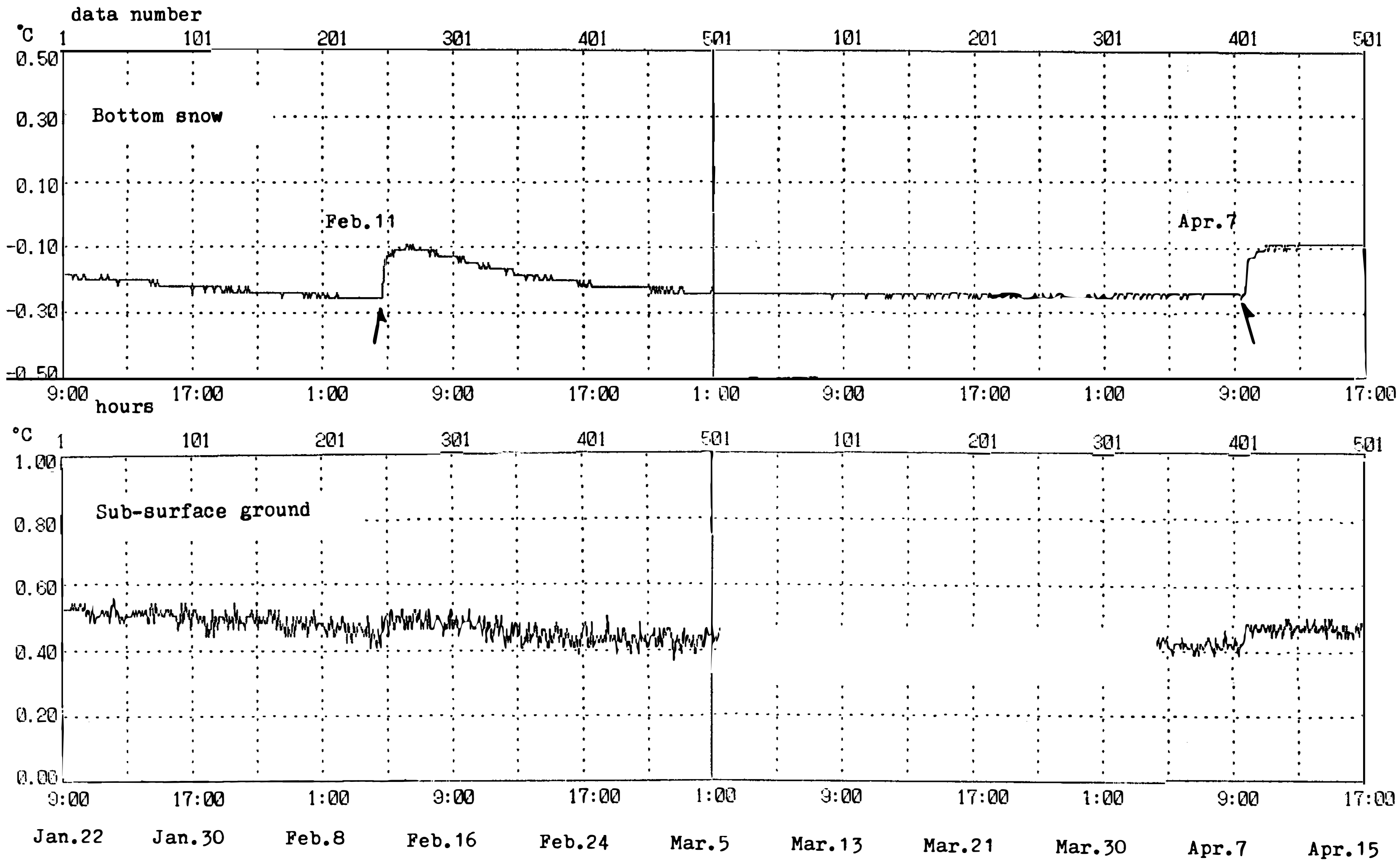

Fig. 3. Temperature of bottom snow and sub-surface ground during the period from late winter to mid-spring, 1987.

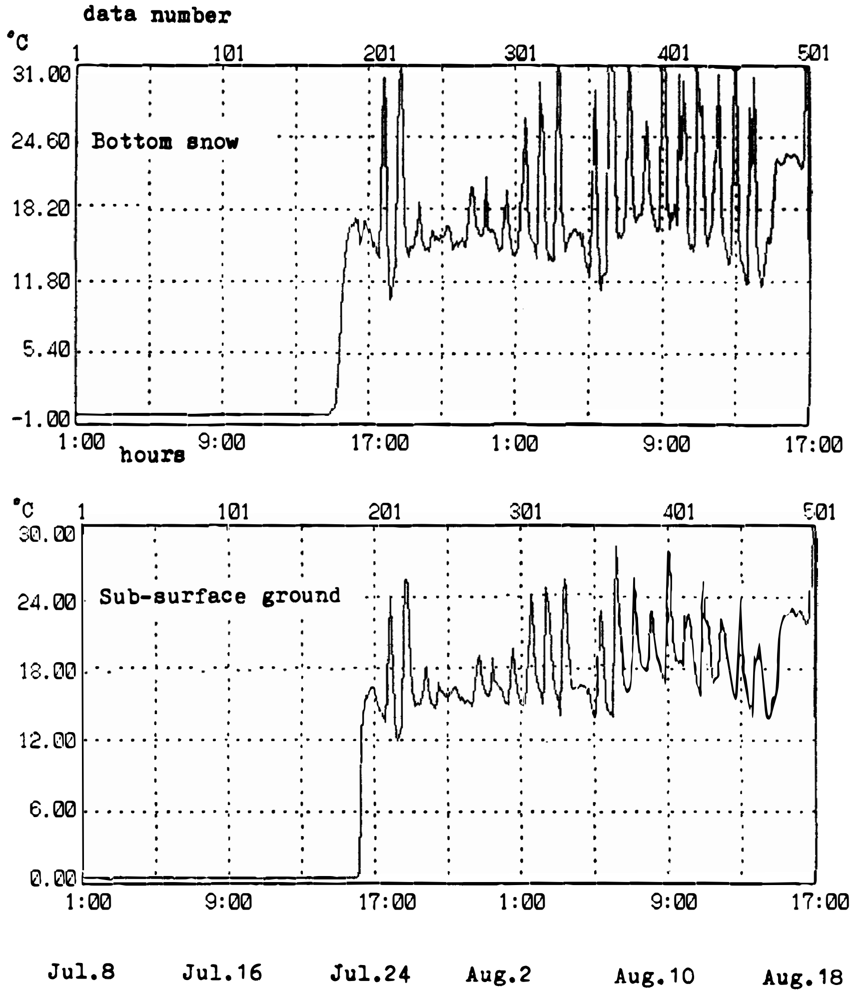

Fig. 4. Temperature of bottom snow and sub-surface ground during days in the latter part of summer, 1987.

tion was November 9. Maximum snow depth at the observation site extracted from the 1974 snow depth map by TSUCHIYA (1984) was estimated to be at least 15 meters or more in late March; however, the amount of snowfall in the winter of 1986/87 was less than in usual years. The snow-melting increased day by day in April; and several bear-size rocks around the observation site were exposed in mid-July; then the ground surface appeared in the afternoon hours on July 22 according to the temperature record by one RMT thermometer.

The two RMT thermometers were collected on August 16, 1987, and memory records of 8000 h were printed by a personal computer system. Figures 2, 3, and 4 show the temperatures in the following 3 period: placement of the thermometers and the following days in autumn; days from late winter to mid-spring; and days in the latter part of summer, respectively . Low temperatures at 1300 on September 19 are the records from the melting snow bed and were recorded simultaneously by the two RMT thermometers. Air temperatures were recorded during the period from 1900 on August 16 to 0700 on August 17 in a room for a calibration of time and temperature records.

3. Records from Late Winter to Mid-spring

"Haru Ichiban" is one of the remarkable weather phenomena of Japan which occurs in late winter. It is stormy weather which brings sub-tropical warm air mass into higher latitudes, and a polar air mass retreats transiently for several days. The physical process of the deep snow cover in mountains subjected to such weather has been almost unknown, and there have been no observational reports.

We can find two continuous temperature series which show some curious changes (Fig. 3). A trend of moderate decrease in the temperature of the bottom deep snow cover stops, reverting to an abrupt increase of about 0.2°C on February 11, then moderately decreasing again. The second abrupt increase occurs on April 7, then never decreases again during the recording period.

The first abrupt increase is similar in shape to the second increase when a spring thawing reaches to the bottom of the snow cover. We can assume that a partial spring-like thawing phenomenon occures for several hours or more in the first half of this late winter period.

Figure 5 shows two weather maps on February 10 and 11, 1987. A very strong "Haru Ichiban" was brought by an extratropical cyclone which rapidly developed and moved northeast in the Japan Sea. Anomalous warm air warmed the deep snow cover in mountains and melted water dropped rapidly. The amount of melt-water is rather large; thus the water percolates to the deepest part of the snow cover although the refreezing process partly existed in the thick snow layer. Such abrupt snow temperature increase was slightly reflected to the sub-surface ground temperature. Then we can say that the heat from an anomalous warm air was mostly absorbed by the thick snow.

The second abrupt bottom snow temperature increase occurred on April 7 and did not decrease until the disappearance of the snow cover. And the temperature was at an almost steady level.

In the sub-surface ground, the temperature records fluctuate with short and long irregular periods which perhaps reflect heat balance irregularities of downward cold from snow cover and upward earth heat flow. In the sub-surface ground, sub-freezing temperature was never recorded during the period of continuous snow cover, which is

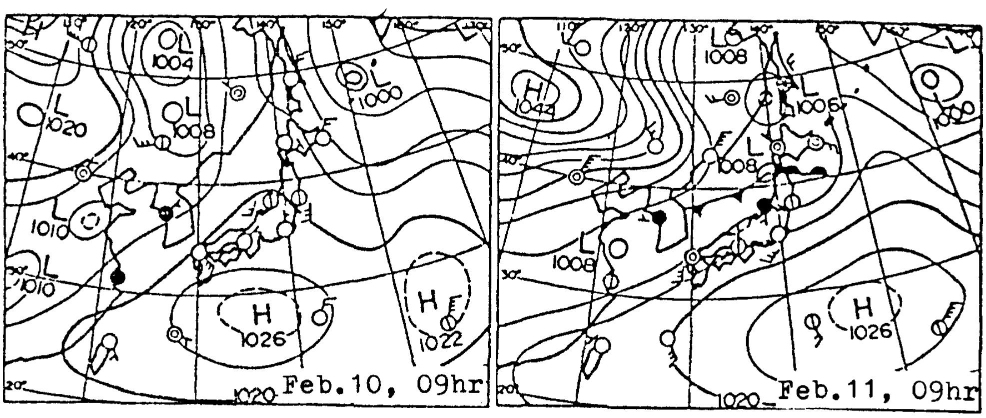

Fig. 5. Weather maps on February 10 and 11, 1987 (from Japan Meteorological Association).

different for the sub-freezing record by YOSHIDA (1986) on a wind-blown slope with a little snow cover in the alpine zone of Mt. Kisokomagatake, in Central Japan.

4. Further Remarks

The interaction between the deep snow cover in mountains and air masses from polar or subtropical regions is an important matter from the viewpoints of water resources and natural disasters. This paper focuses on the interpretation of temperature records from the deepest deposited snow and the sub-surface ground which underlies the deep snow cover; the aerological data are not yet published.

The snow depths at the observation site on the last days of January and March are estimated to be about 10 and 15 m or more, respectively, and they are about 5 meters lower than in usual years. And the snow depth above Kaigata Glacieret was about 25 m on the last day of March, 1987. These estimations are based on the previous observations (TSUCHIYA, 1984) and dates in the process of disappearance of remnant snow cover in 1987.

There are two possible mechanisms of heat transfer from warm air or water into snow or ice. The first is heat conduction. If we assume the linear heat flow into a mass of ice, we can use a simple time delay (t) equation,

$$t=\rho c a^2/2\kappa$$

where ρ is density, κ is thermal conductivity, c is specific heat, and a is convenient depth increment. An example of temperature change time estimation of an iceberg by DIEMAND (1984) shows that the t for a depth increment of 0.5 m is 1.14 days and for a depth increment of 2.5 m is 28.6 days. At our observation site, the snow depth is estimated for 10 m or more in February and snow requires more days for heat transfer than ice; then we can assume that the t is several hundred days. And the change of surface snow temperature does not affect for several days the bottom snow of 10 m depth.

The second and major mechanism is the heat transfer by percolation of snow melt-water or rainwater. Water on the snow surface percolates and rapidly drops to the bottom snow until the beginning of the refreezing process. Some melt-water has existed with snow and ice during several or more hours until the water supply has stopped, when a near freezing temperature was recorded at the bottom snow. But this mechanism needs considerable warm rainfall or snow melt-water, namely an effective influence of stormy warm weather; a strong "Haru Ichiban" is such weather.

Air temperature at the observation site exceeded 5°C during the event of "Haru Ichiban" on February 11, 1987; the day after, several stormy warm weather events reached the coast of the Japan Sea and surrounding regions; however, the temperature of these warm weather events was not very high according to my estimation based on the reports by the JAPAN METEOROLOGICAL AGENCY (1987), and there was no change in the bottom snow temperature until the end of the winter season, *i.e.*, on April 7, 1987.

There were similar but small changes in the sub-surface ground temperature during the event of "Haru Ichiban". Two RMT thermometers recorded an influence of a transient retreat and advance of polar air mass, and also temperatures indicating an end of winter or a beginning of the essential spring under the deep snow.

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(Received February 8, 1988; Revised manuscript received October 1, 1988)