Variation of snow and winter air temperatures in the last 60 years at Shinjo, Japan

By

Tsutomu Nakamura
Nagaoka Institute of Snow and Ice Studies,
National Research Institute for Earth Science and Disaster Prevention, STA
Suyoshi, Nagaoka 940, Japan

and

Osamu Abe
Shinjo Branch of Snow and Ice Studies,
National Research Institute for Earth Science and Disaster Prevention, STA
Tokamachi, Shinjo 996, Japan

Abstract

Smaller amounts of snow in the last 8 winters from 1986/87 to 1993/94 at Shinjo seems to be due to winter air temperature rise. Rate of temperature rise in the last century was calculated as 0.58°C/100years. The max snow depth and winter precipitation showed an inversed positive correlation with winter mean air temperatures. The max snow depth and the max winter precipitation have the max in 1936. The max snow depth and the second max precipitation which were obtained from statistically smoothed curves were found in 1940. Fluctuation in deviation of the max snow depth showed smaller values than in precipitation. The minimum of winter mean air temperature obtained from a statistically smoothed curve was found in 1940, and a rapid temperature rise was observed since around 1980. The rise in temperature might show the global warming.

INTRODUCTION

Snow is an indicator of the coldness. Variation of the snow, therefore, could be a measure of the global change. The role of snow should be emphasized and has been discussed from a global change point of view (Meier, 1984; Houghton et al, 1990; Hall et al, 1992; World Data Center, 1993). On the other hand, snow is a water resource and also a disastrous impact for the man. Tohoku District of the Honshu Island, Japan has been suffered from heavy snowfalls as well as the Hokuriku District of Japan though the max snow depth is deeper in the Hokuriku District than in the Tohoku District. Therefore, residents in the snowy area of Japan desire a rigorous prediction of snow. In these heavy snowfall winters, some hundred people were killed due to these heavy snowfalls. For example in the 1963 winter, we named it the 38-Gosetsu winter, 231 persons were killed (Takahashi and Nakamura editors, 1992). In such a heavy snowfall winter the amount of snow on the Japanese Islands was calculated as 1.3×10^{14}kg in 1980/81 winter (56-Gosetsu) compared with the amount of 7.9×10^{13}kg as the average (Nakamura and Abe, 1993).

In the previous paper (Nakamura and Shimizu, presented as posters at the IGS Ohio meeting, 1994) the authors discussed the variation of snow and winter air temperatures at Nagaoka which is located in the middle of the heaviest snowfall area in Japan. The authors of the present paper intend to discuss the variation of snow and winter air temperatures at Shinjo which is located at

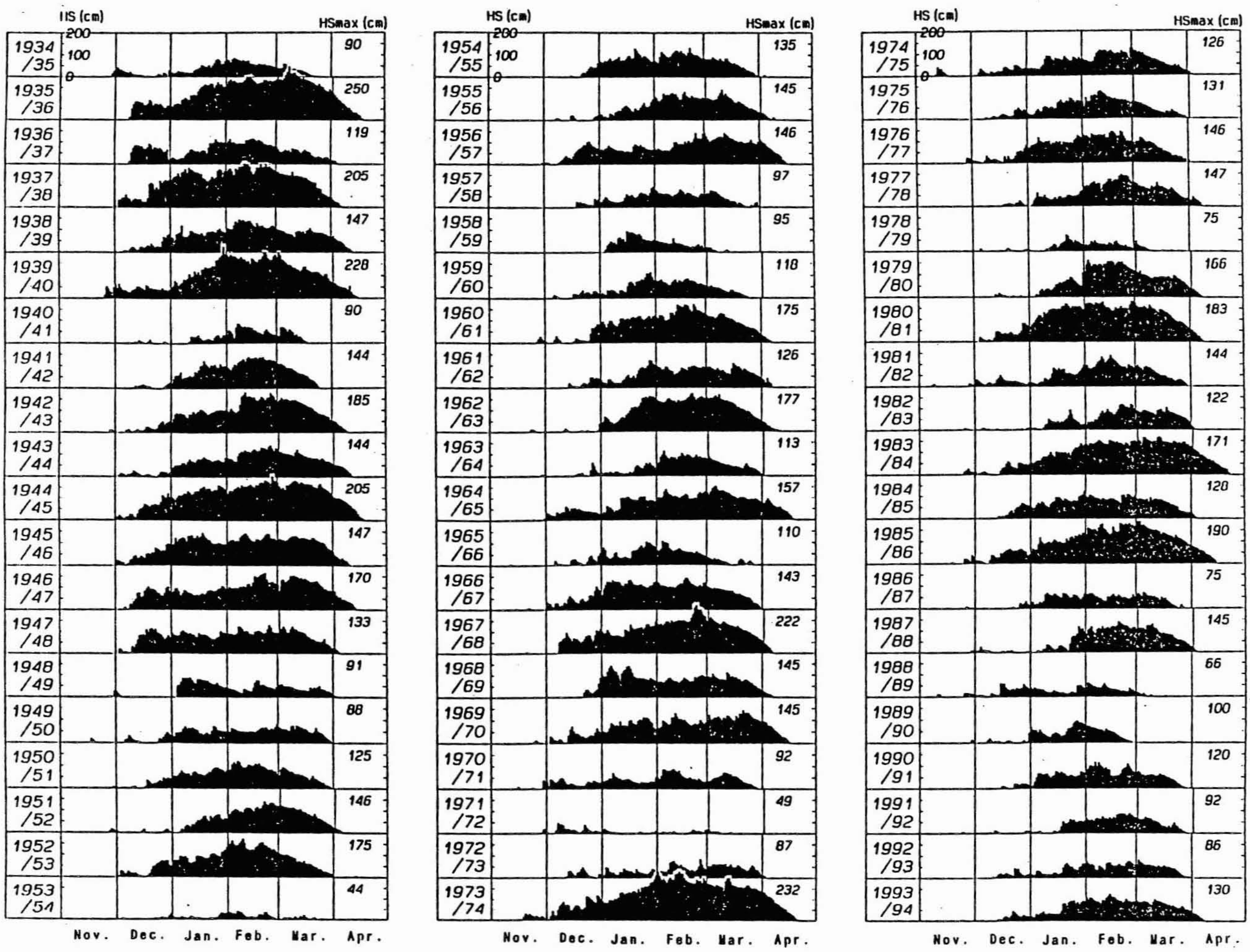

Fig. 1 : Annual and daily changes of snow cover on the ground at Shinjo in Tohoku district (1934/35 to 1993/94 winters). One pattern corresponds to one winter.

Table 1 Data sources of the max snow depth

Years	Publications et al
1934/35 - 1973/74	Shinjo Meteorological Observatory
1974/75 - 1983/84	Abe et al (1985)
1983/84 - 1993/94	Abe et al (in preparation)

Table 2 Data sources of air temperatures and precipitation

Years	Publications
1934 - 1952	Report of the Meteorological Observatory Shinjo for 1934-1952. Snow Association & Shinjo Meteorological Observatory (1953)
1953 - 1957/Aug., 1985 - 1994	Meteorological Data of Yamagata (Yamagata Meteorological Observatory, Monthly data report)
1957/Sept. - 1984	Climate of the Tohoku Area (Sendai District Meteorological Observatory, 1986)

the middle of the Tohoku District of Honshu Island, the main island of the Japanese Islands.

GEOGRAPHIC CHARACTER OF SHINJO.

Shinjo (38°47'N, 140°19'E, 127m msl) is located in the middle part of the Hokuriku District of the Honshu Island of Japan. Clouds, origins of snowfalls, develop over the Sea of Japan. The sea is a water vapor origin to produce the clouds. The distance along the line from the nearest coast of Shinjo (40km away from the coast) to the Asiatic Continent is about 900km. This reflects active snow cloud development on the sea of Japan. Shinjo is surrounded by small mountains, too. Therefore, snowfall is affected by the topography. As Shinjo is located in the Shinjo Basin the amount of snow is steady. Therefore, Shinjo could be one of the best points to know the snow amount as an indicator of the global change. Figure 1 shows annual and daily changes of snow cover measured on the ground at Shinjo from 1934/35 to 1993/94 winters. One pattern corresponds to one winter. Snow in Shinjo varies rather steadily year to year with very small amounts of snow in some winters. The area of the pattern shows the amount of snowfall in a winter. The max snow depth is also a measure of the amount of snow as seen in the figure. The max snow depth appears mostly in February. In this paper, therefore, the max snow depth on the ground is used as an indicator of the snow amount.

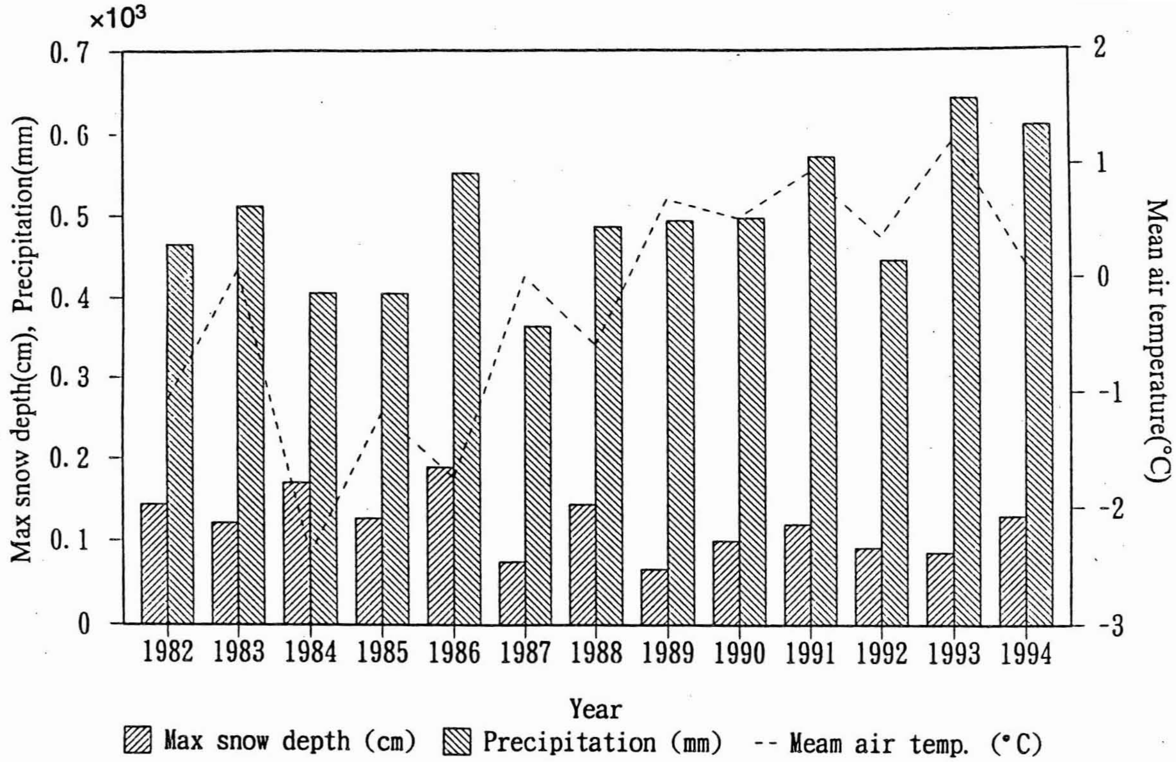

Fig. 2 : Temporal variation in the max snow depth (cm), precipitation (mm) and mean air temperature (°C) of winters (DJF) from 1982 to 1994.

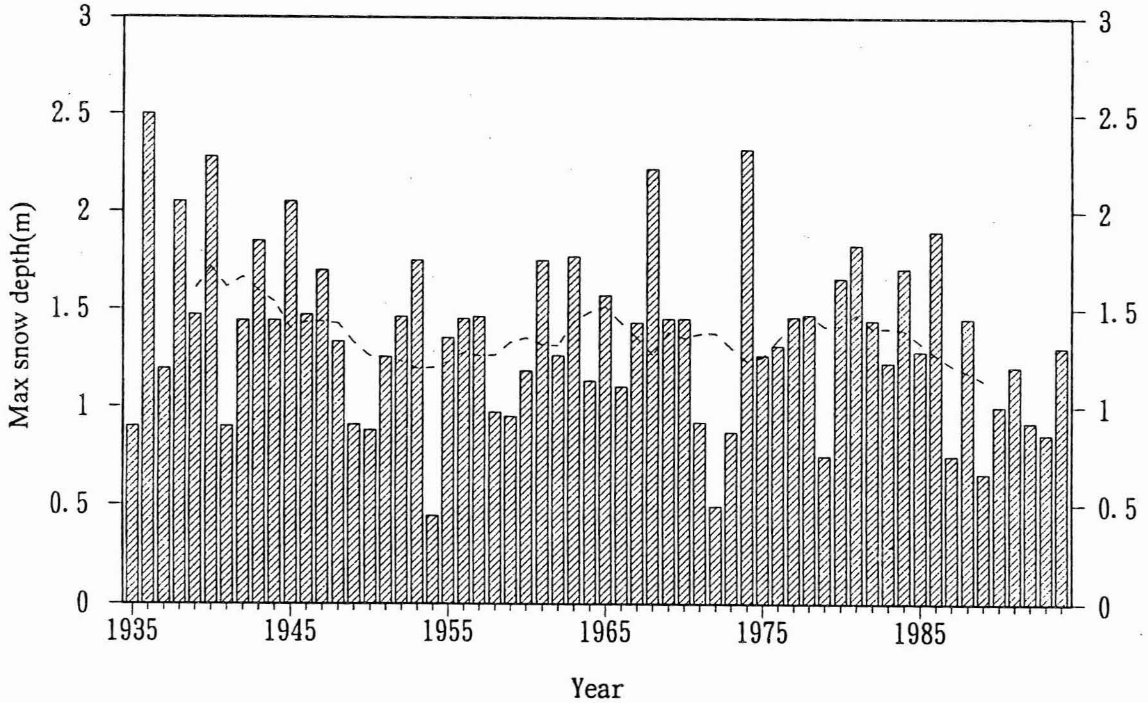

Fig. 3 : Temporal variation of the max snow depth (m) from 1935 to 1994 in Shinjo. A smooth curve is a filtered value designed to show decadal and longer time-scale trend more clearly.

DATA SOURCE

Data of the max snow depth analyzed in this paper was taken from two sources. The one from 1934/35 to 1973/74 came from the Japanese Meteorological Agency in Shinjo, the other from 1974/75 to 1993/94 came from the Shinjo Branch Data. Precipitation and air temperature data from 1934/35 to 1993/94 were collected from the publications by the Japanese Meteorological Agency in the Yamagata area. The detailed data sources are shown in Tables 1 and 2.

SNOW AND WINTER AIR TEMPERATURE IN THE RECENT 13 YEARS AT SHINJO

Figure 2 shows the observed max snow depth on the ground, precipitation in winter (December to February) and winter (DJF) mean air temperatures from 1982 to 1994 at Shinjo. This figure shows that in the last 13 winters precipitation has gradually increased though the max snow depth rather decreased since 1986/87 winter. The decrease of the max snow depth seemed to be due to the winter mean air temperature rise as shown in the figure.

SNOW AND WINTER AIR TEMPERATURES IN THE LAST 60 YEARS AT SHINJO

Figure 3 shows annual variation of the max snow depth measured on the ground from 1934/35 to 1993/94 at Shinjo. In the last 60 years the max snow depth of 2.50m was observed in the winter of 1935/36 of the mean depth of 1.36m with standard deviations of

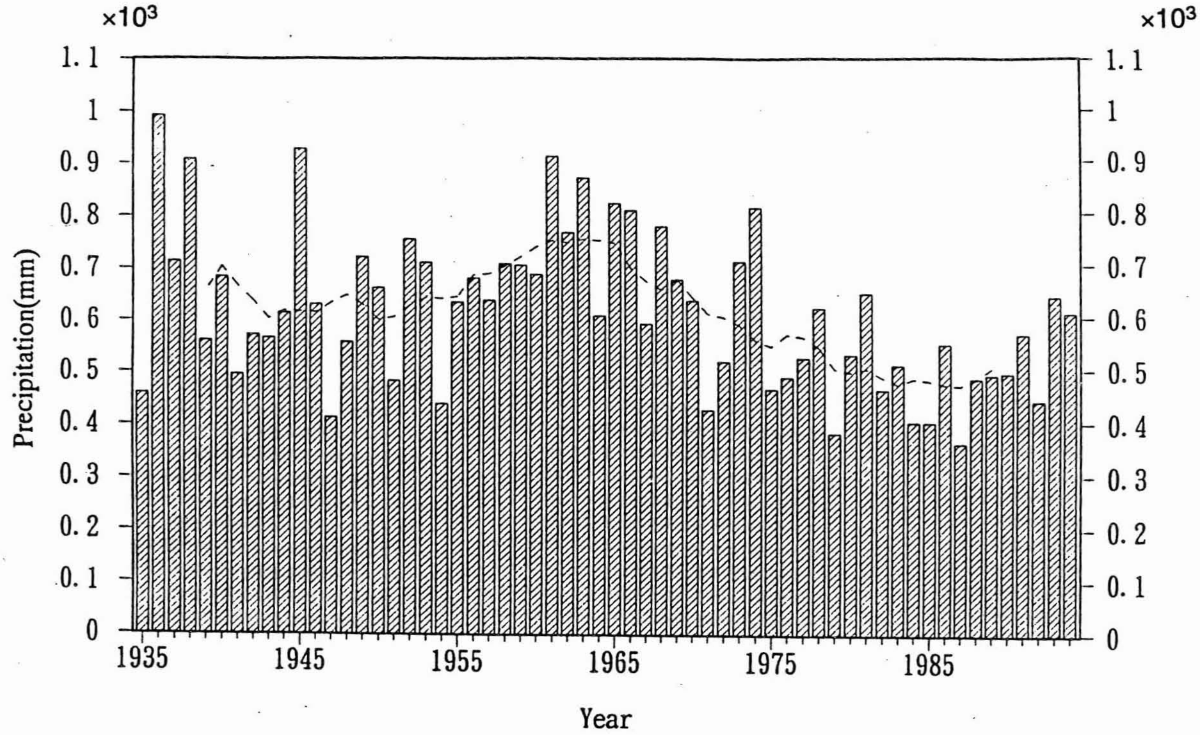

Fig. 4 : Temporal variation of precipitation (mm) in winter (DJF) from 1935 to 1994 at Shinjo. A smooth curve is a filtered value designed to show decadal and longer time scale trend more clearly.

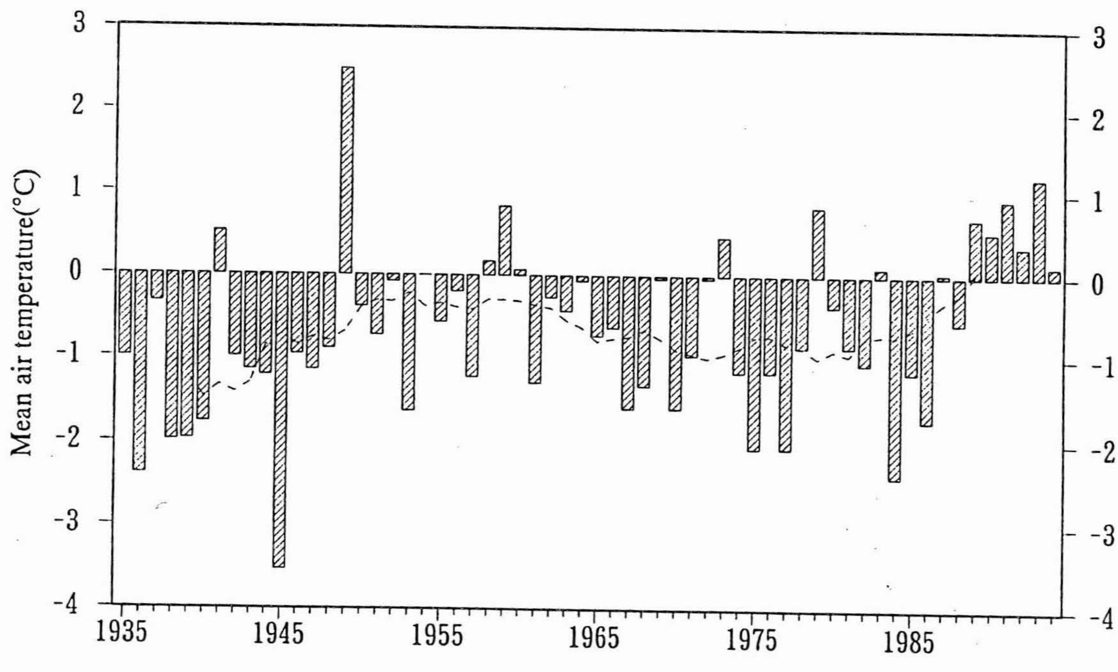

Fig. 5 : Temporal variation of mean air temperature (°C) in winter (DJF) from 1935 to 1994 at Shinjo. A smooth curve is a filtered value designed to show decadal and longer time-scale trend more clearly.

0.44m. A smooth curve is a filtered value designed to show decadal and longer time-scale trend more clearly. Figure 4 shows annual variation of the winter (December to February) precipitation measured in Shinjo. The max value of 992.5mm was found in 1935/36 of the mean of 615.8mm with standard variations of 147.5mm. A smooth curve is a filtered value as in the max snow depth. Figure 5 shows annual variation of the winter (DJF) mean air temperatures measured at Shinjo. The max. and min. mean air temperatures were observed in 1949 and 1945, respectively. The max. and min. mean air temperatures were observed in the same years of 1949 and 1945, respectively at both Shinjo and Nagaoka (Nakamura and Shimizu, in preparation). The annual winter mean air temperature in the past 60 years at Shinjo was -0.66°C with a standard variation of 1.0°C. The same standard variation was observed in Nagaoka, too. In almost all the years in the last 60 years winter mean air temperatures in Shinjo were observed negative expressed in Celsius, but in the recent 6 years the temperatures were observed positive. A smooth curve in Fig. 5 is also drawn as in the max snow depth and in the precipitation. The minimum of winter mean air temperature obtained from a statistically smoothed curve is found in 1940, and a rather rapid temperature rise is observed since around 1980. Figure 6 shows annual variation of the decadal filtered value of the winter mean air temperature with a regression line of the filtered values obtained in 1935 to 1994. The equation of the regression line with a correlation coefficient r was expressed as;

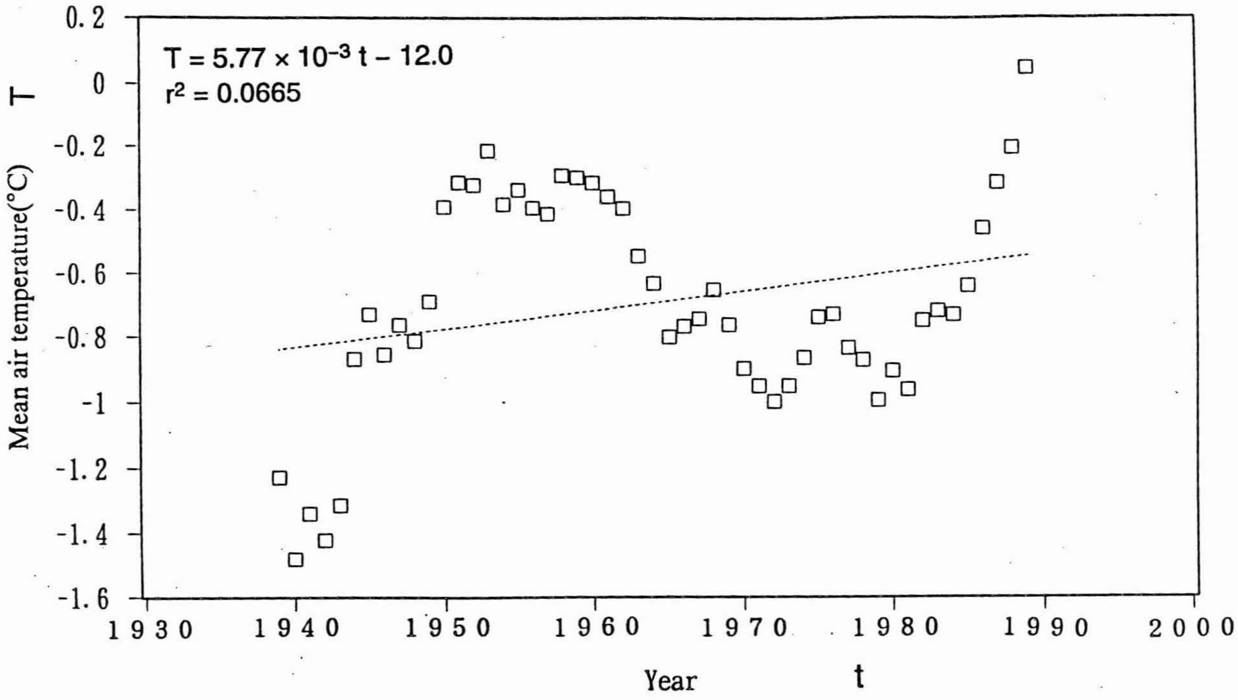

Fig. 6 : Variation of the mean air temperature (DJF) filtered with decades in Shinjo with a monotonic trend line.

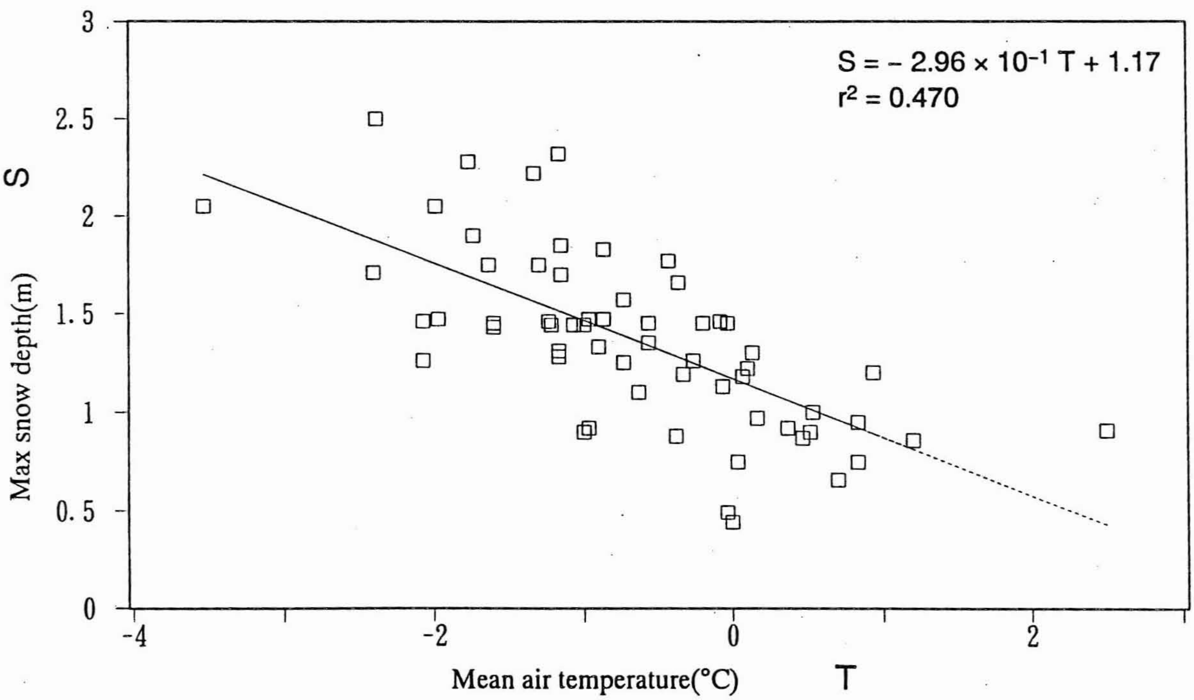

Fig. 7 : Correlation between the max snow depth (m) and the mean air temperature (°C) in winter (DJF) from 1935 to 1994 at Shinjo.

$$T = 5.77 \times 10^{-3}\ t - 12.0 \cdots\cdots\cdots\cdots(1),$$
$$r^2 = 0.0665,$$

where T is winter mean air temperature in °C and t year in AD. The equation means that the temperature rise in the past 60 years was 0.35°C. If we extended this rate in the last century, the increase is 0.58°C.

Correlation between the max snow depth and the winter mean air temperature measured on the ground at Shinjo was shown in Figure 7. The figure shows that there is an inversed negative correlation between the max snow depth and the mean air temperature. The regression equation with a correlation coefficient r was expressed as;

$$S = -\ 2.96 \times 10^{-1}\ T + 1.17 \cdots\cdots\cdots\cdots(2),$$
$$r^2 = 0.470,$$

where S is the max snow depth in cm and T winter mean air temperature in °C. Figure 8 shows a positive correlation between the winter precipitation and the max snow depth. The regression line with a correlation coefficient r was expressed as;

$$P = 174.5\ S + 378.0 \cdots\cdots\cdots\cdots(3),$$
$$r^2 = 0.275,$$

where P is precipitation in mm and S the max snow depth in cm.

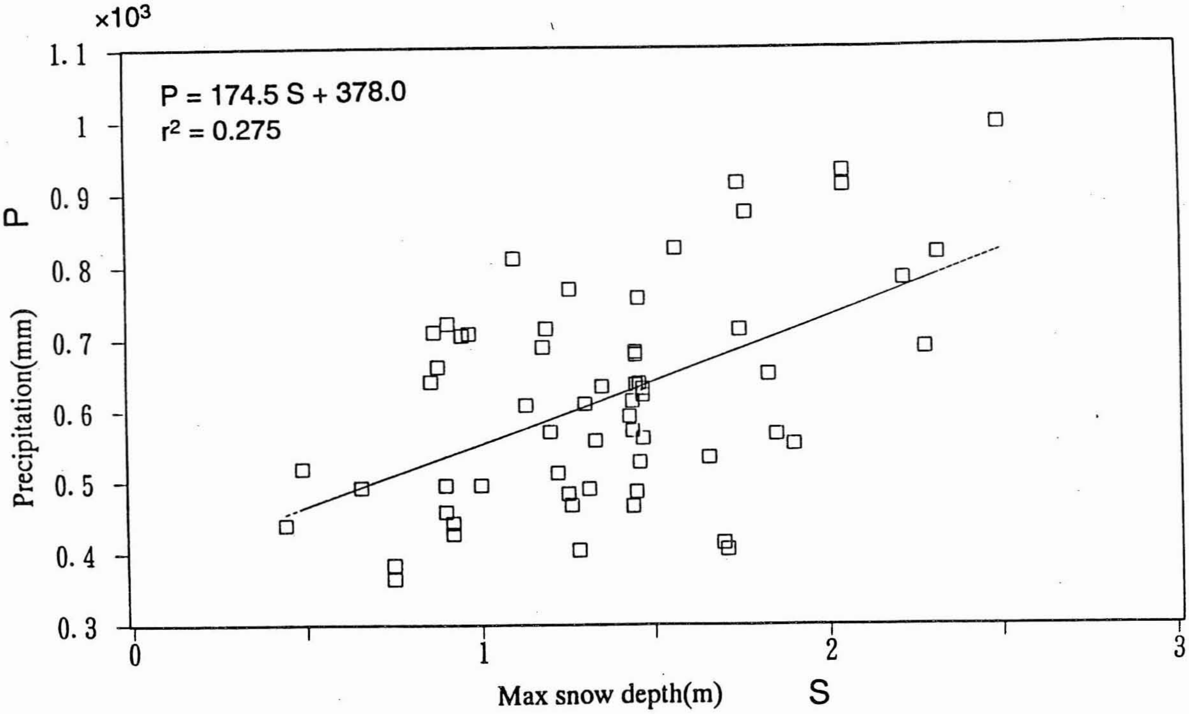

Fig. 8 : Correlation between the precipitation (mm) in winter (DJF) and the max snow depth (m) from 1935 to 1994 at Shinjo.

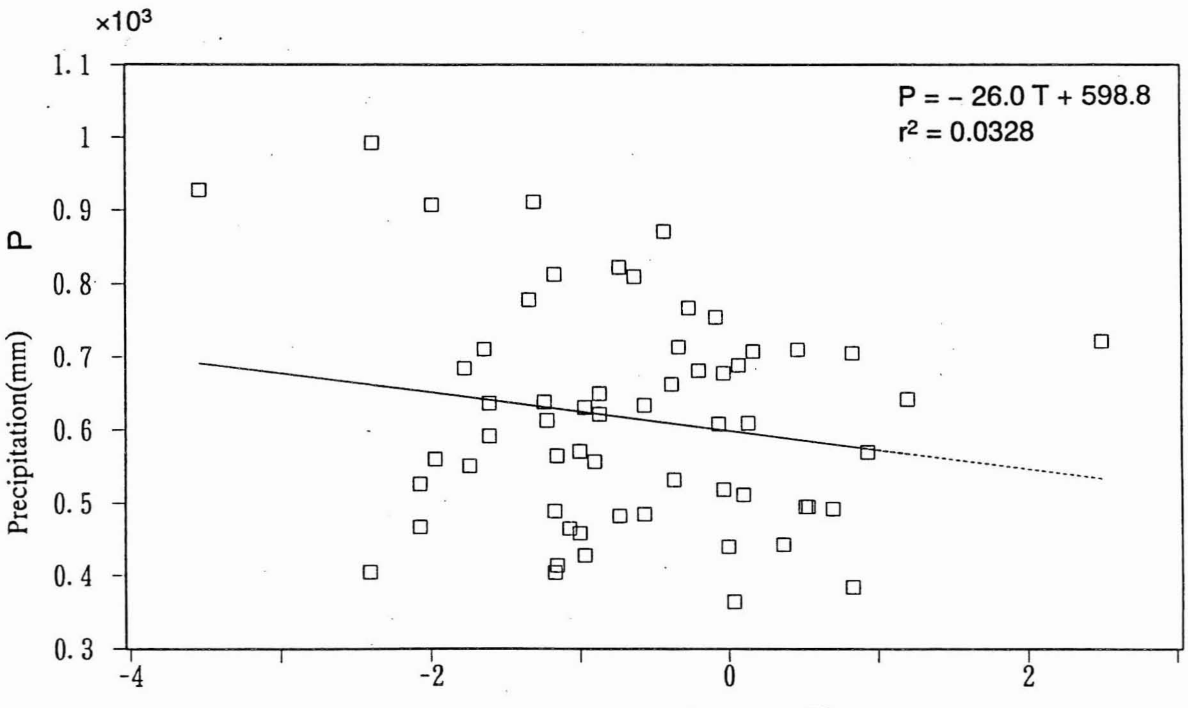

Fig. 9 : Correlation between the precipitation (mm) and mean air temperature (°C) in winter (DJF) from 1935 to 1994 at Shinjo.

As shown in Figure 9 winter precipitation decreases as the winter mean air temperature increases. The regression line with a correlation coefficient r was obtained as;

$$P = -26.0\,T + 598.8 \cdots\cdots\cdots (4),$$

$$r^2 = 0.0328,$$

where, P is precipitation in mm and T mean air temperature in °C. Figure 10 shows annual variation of the three decadally filtered values of the max snow depth, winter mean air temperature and winter precipitation in Shinjo. As shown in Fig. 10 both values of the max of the snow depth and of winter precipitation were found in 1940 with the minimum mean air temperature. Magnitudes of the temperature correspond well to the magnitudes of both the max snow depth and precipitation in opposite sign. Also the temperature changes correspond fairly well to the changes of the max snow depth in inversed direction. For example, increase of the temperature from 1940 to 1953 corresponds to the decrease of the max snow depth. Also increase of the air temperature from 1979 to the present time reflects to the decrease of the max snow depth. Also it is shown in Fig. 10 that small peaks of air temperatures corresponds to the troughs of the max snow depth and vice versa.

Figure 11 shows annual variations of the three values of the max snow depth, winter precipitation and mean air temperature ex-

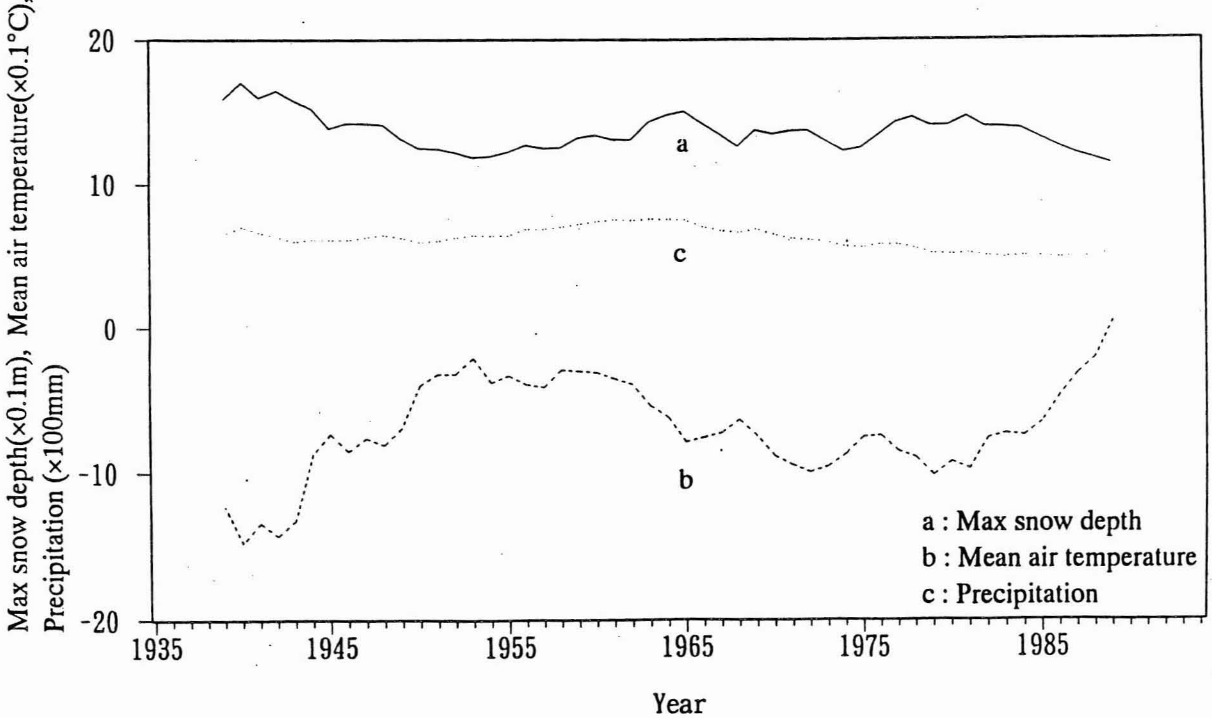

Fig.10 : Inversed positive correlation between the maximum snow depth on the ground (a) and the mean air temperatures (b) in Shinjo in the last 60 years. Also inversed slight positive correlation between the precipitation (c) (DJF) and the air temperature is seen.

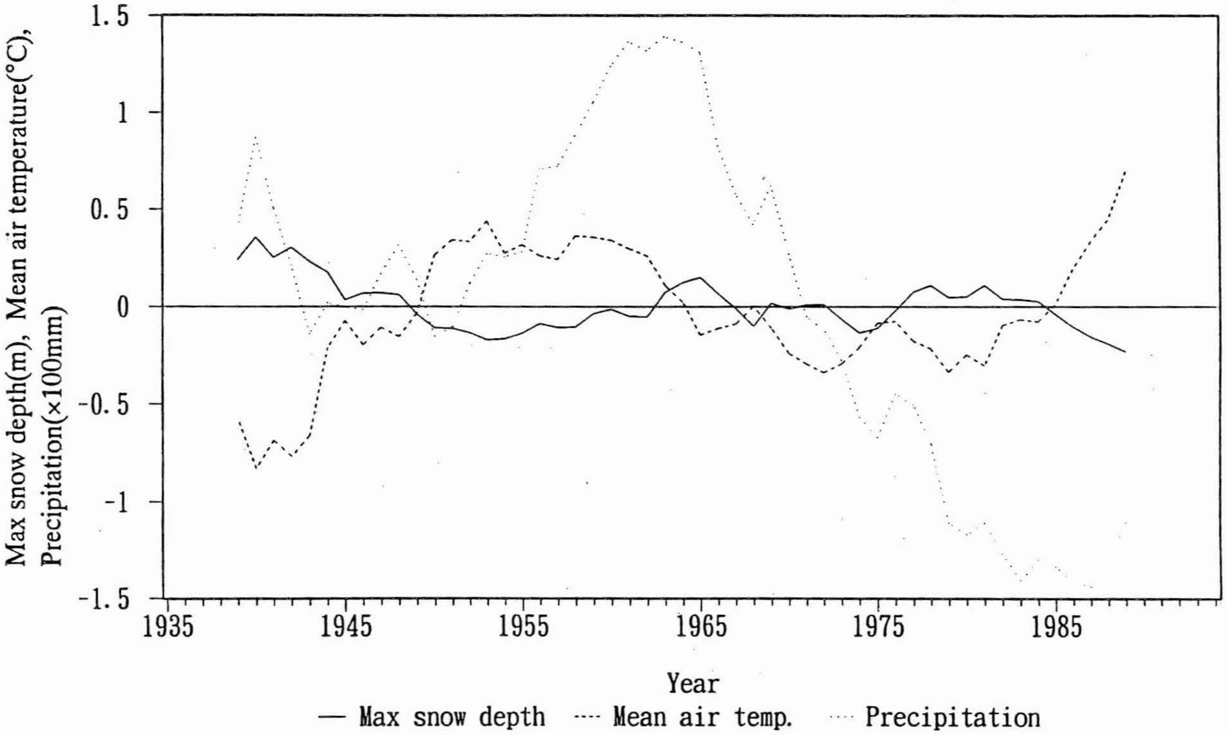

Fig.11 : Temporal variations of the deviations from the climatic mean in the max snow depth, precipitation and mean air temperature in the last 60 years at Shinjo.

pressed in deviations from the 60 year's climate mean.

The max snow depth has a mean value of 1.36m with standard deviations of 0.44m. Precipitation mean is 615.8mm with standard deviations of 147.5mm. Annual mean air temperatures in the last 60 years were -0.66°C with a standard deviation of 1.0°C.

When we looked at the Fig. 11 carefully, the figure tells us that the change of winter air temperatures correspond to the change of the max snow depth in opposite sign, i.e., increase or decrease of the temperature corresponds to the decrease or increase of the max snow depth respectively. But increase or decrease of the temperature does not correspond necessary to the decrease or increase of the precipitation. In some years the increase of the air temperature corresponds to the increase of precipitation. The years are from 1943 to 1944, 1950 to 1953, 1957 to 1958, 1968 to 1969, 1974 to 1975 and 1987 to 1989. Here we should recognize the Fig. 11 shows filtered values designed to show decadal and longer time-scale trend more clearly.

DISCUSSION AND CONCLUSIONS

Decrease of the max snow depth in the ground in the recent 8 years in comparison with the previous seven winters at Shinjo seemed to be due to the air temperature rise in winters as shown in Fig. 2, though precipitation in recent winters itself has increased slightly. As shown in Fig. 6 variation in the winter(DJF) mean temperature of the decadally filtered values showed a gradual increase in the last 60 years with some peaks and troughs. General tendency is the same as the one reported by Houghton et al (1990). Some of them in our present paper, i. e., a recent temperature rise since 1984, two troughs in 1980 and 1972, two peaks around 1958 and 1953, and a decrease from 1953 to 1940 correspond to a temperature rise since 1985, two troughs in 1977 and 1969, two peaks in 1960 and 1952, and a decrease from 1952 to 1940 in the report (Houghton et al, 1990) obtained in the 20 to 50°N, but a trough, namely, the minimum value found at Shinjo around 1940 is not found in the Houghton's report. The linear increase rate was calculated as 0.35°C/60years, so we may say 0.58°C/century. The rate corresponds well to the upper rate of around 0.6°C over the past 80 to 100 years reported by Houghton (1990).

It was found that there is an inversed positive correlation between the max snow depth and the winter precipitation, and the mean winter air temperature, namely if the air temperature decreased the max snow depth and the precipitation increased.

Precipitation in the last 60 years has the max in 1963. The second maximum value is found in 1940 as shown in Fig. 11.

The max value of the max snow depths was found in 1940 which does not necessarily corresponds to the max of precipitation as shown in Fig. 11. Fluctuation of the deviation of the max snow depth from the climatic mean did not show so big values as compared with the fluctuation of the precipitation.

The minimum of the winter mean air temperature observed in a statistically smoothed curve was found in 1940, and deviation from the climatic mean changed around the mean in the last 60 years. But a rather rapid increase of the temperature is observed since around 1980. The change could be due to the global warming.

Winter air temperatures in both Shinjo and Nagaoka showed a quite similar pattern. Recent temperature rise was observed in these two areas. Also two peaks in 1968 and 1975 were found in the two areas. In Shinjo other two peaks are found in 1952 and 1958. We may say we have one peak between 1950 to 1960 from a smoothed global variation point of view then we may say this peak correspond to one peak in around 1960 at Nagaoka. Also in these two areas the minimum air temperature obtained from a statistically smoothed curve in the last 60 years is found in 1940.

If the global temperature rise proceeds in future, it is said that snow in Shinjo will decrease, as there is an inversed positive correlation between the max snow depth on the ground and winter air temperature in Shinjo. In Nagaoka, it was statistically shown that there is a correlation between a heavy snowfall year corresponds to La Niña year (Sue et al, 1994). Further investigation is necessary to predict snow in Shinjo as well as in Japan from many points of view including the Asian monsoon.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Ms. Mayumi Koizumi for her help in the statistical calculation and typing of the manuscripts. Acknowledgement is also given to the Japanese Meteorological Agency in Yamagata and colleagues at Shinjo Branch for their meteorological observation in a long period.

REFERENCES

Abe, O. et al. 1985. Snow Depth and Weather Observed for Ten Winter Seasons at the Shinjo Branch of the NRCDP. Review of Research for Disaster Prevention, No. 131, pp.138.

Ferguson, S., P. Hayes, T. Nakamura, T. Ikarashi and Y. Yamada. 1994. The climate of major avalanche cycles. World conference on Natural Disaster Reduction, Yokohama.

Hall, D. K., R. S. Williams, Jr., and K. J. Bayr. 1992. Glacier Recession in Iceland and Austria. EOS, 73, 129, 135 and 141.

Houghton, J. T., G. J. Jenkins and J. J. Ephraums editors. 1990. Climate Change. The IPCC Scientific Assessment, Cam bridge, 1-364.

Meier, M. F. 1984. Contribution of Small Glaciers to Global Sea Level. Science, 226, 1418-1421.

Nakamura, T. and O. Abe. 1993. Estimated seasonal snow cover and snowfall in Japan. Annals of Glaciology, 18, pp.179-184.

Nakamura, T. and M. Shimizu. (in preparation). Variation of snow and winter air temperature in the last century at Nagaoka, Japan (Presented as posters at the IGS Ohio meeting, August, 1994)

Sendai District Meteorological Observatory. 1986. Climate of the Tohoku Area (Tōhoku-chihō no Kikō), pp.104.

Snow Association and Shinjo Meteorological Observatory. 1953. Report of the Meteorological Observatory Shinjo for 1934-1952, pp.98.

Takahashi, H. and T. Nakamura. 1986. Snow disasters (in Japanese). Tokyo, Hakua Printing Co., Ltd., Japan.

World Data Center. 1993. Glaciological Data, Report, GD-25, 1-295.

Yamagata Meteorological Observatory. 1953-. Meteorological Data of Yamagata (Monthly data report).