The meteorological condition for larger avalanches at Senjojiki Bowl in Japanese Central Alps

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ABSTRACT. The Senjojiki Bowl has a typical avalanche terrain consisting of 8 avalanche tracks. During the last 25 years 16 alpinists and ropeway workers in total have been killed by avalanches. Since no reliable avalanche warning is issued by the Meteorological Agency, the ropeway company and an alpine guide has collected data on avalanches in the bowl since 1987 for the safety of their guests. Using the data over the last three winters, we have analyzed the meteorological conditions leading to larger avalanches descending. It was found that the larger avalanches occurred only under the following simple conditions: 1. cold snow storm type in high-winter, 2. warmer snowy type in high-winter, 3. wet snowy type in late winter and 4. rain storm type.
Keyword: avalanche, meteorological condition, Japanese Alps.

ACCIDENTS IN THE SENJOJIKI BOWL

The Senjojiki Bowl (*Senjojiki-kaaru* in Japanese) is located in the northern part of Japanese Central Alps in Nagano Prefecture. The Central Alps runs 50 km in length and the ridge line elevation ranges from near 2500 m to 3000 m a.s.l. The bowl is popular among alpinists thanks to year-round access by ropeway, and they visit the bowl also in winter under risk of avalanches (Fig. 1).

During the last 25 years, 34 alpinists and workers have been killed by avalanches in the Central Alps, including 16 avalanche victims in the bowl. Since no concrete avalanche warning has been issued by the Meteorological Agency (due-to absence of avalanche forecaster), the ropeway company, Chuo Alps Kanko Co., Ltd., has tried by themselves to establish avalanche safety criteria for visitors to the bowl.

Toshio Kinoshita, an experienced alpine guide, who commutes to the bowl as a manager of the ropeway station hotel, has observed daily activities of avalanches in the bowl since 1987, and he has given appropriate advices on alpine and avalanche safety to bowl visitors.

There is the Nishikoma sub-alpine forest of the Shinshu University 3 km north of Senjojiki, and we, avalanche specialists at the university, started the survey of snow and avalanche in and around the Nishikoma Forest and the Senjojiki Bowl in 1995 (Fig. 2). Under close ties with T. Kinoshita and the Chuo Alps Kanko, by using invaluable Kinosita data, we have analyzed the avalanche conditions in the Senjojiki Bowl.

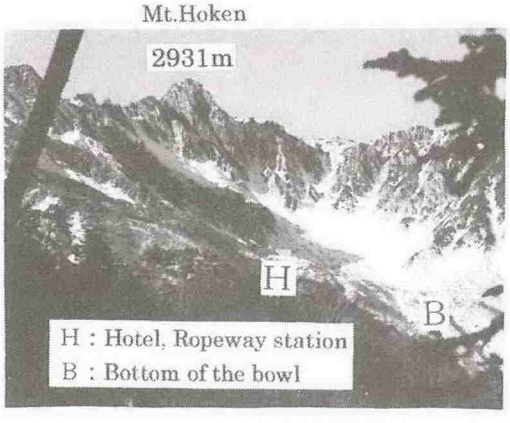


Fig. 1 Senjojiki Bowl.

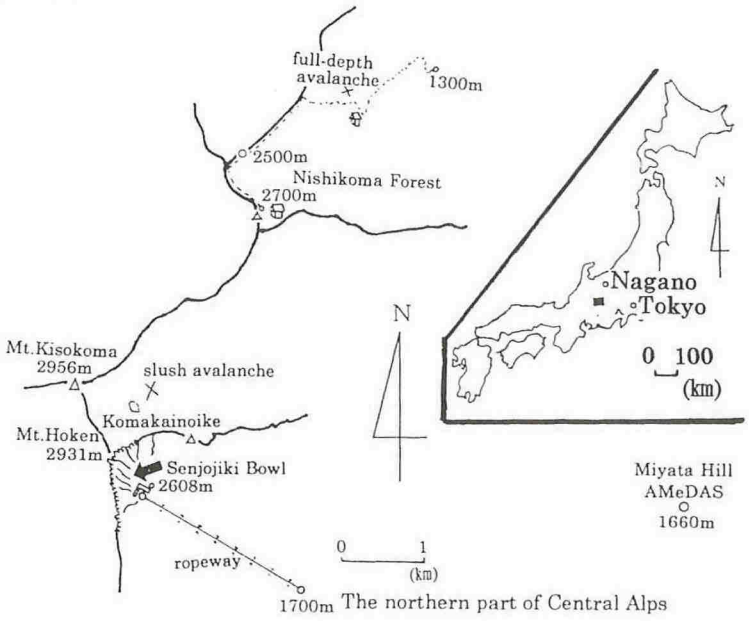


Fig. 2 Location map. The northern part of Central Alps

NATURAL AVALANCHE ACTIVITY

The east to south facing bowl forms a typical avalanche terrain, consisting of 8 avalanche tracks (Fig. 3). The avalanche activity during the last three winters (1994/95 - 1996/97) is analyzed by the size and number of avalanches from daily record. The size and range used are shown in Fig. 4. The activity of L- and LL-sized avalanches, which reach the normal route to the ridge, is summarized in Table 1.

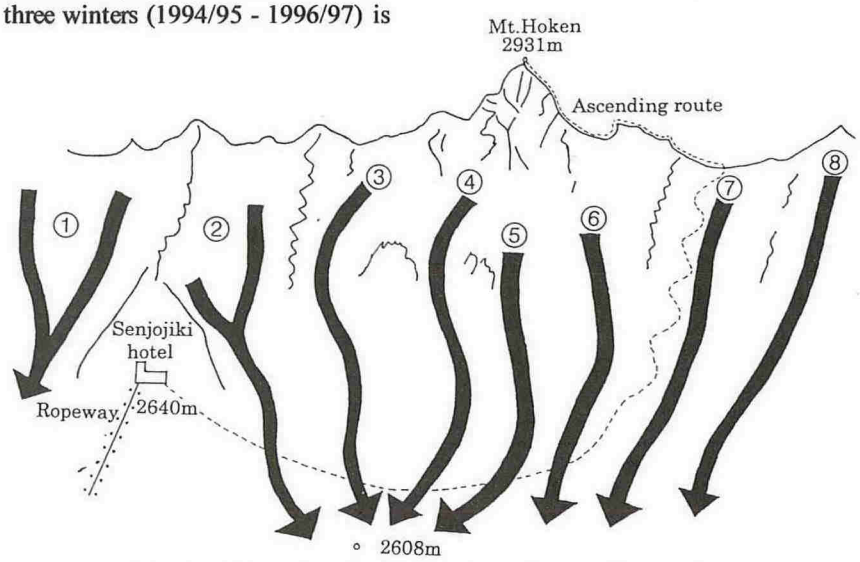
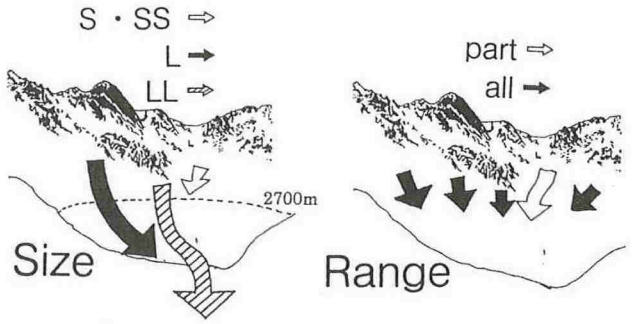


Fig. 3 Map of avalanche tracks and ascending route. Ascending route passes from near the bottom to ⑦ track.



S・SS : Avalanche stops midway down the bowl.
L : Avalanche reaches bottom of the bowl.
LL : Avalanche passes over lip of the bowl.

part : Avalanche descends along some tracks in the bowl.
all : Avalanches descend along almost all tracks in the bowl.

Fig. 4 Classification of the daily bowl avalanches

Table 1 Number of L and LL avalanches

Track	①	②	③	④	⑤	⑥	⑦	⑧	L / L+LL
Gradient	34° 26′	37° 07′	34° 41′	43° 32′	44° 58′	39° 20′	41° 11′	34° 02′	Total number of days
1994/95	2	1	3	5	4	4	1	0	5
1995/96	3	3	3	3	3	3	2	3	3
1996/97	5	4	3	5	8	4	2	3	9
Total	10	8	9	13	15	11	5	6	

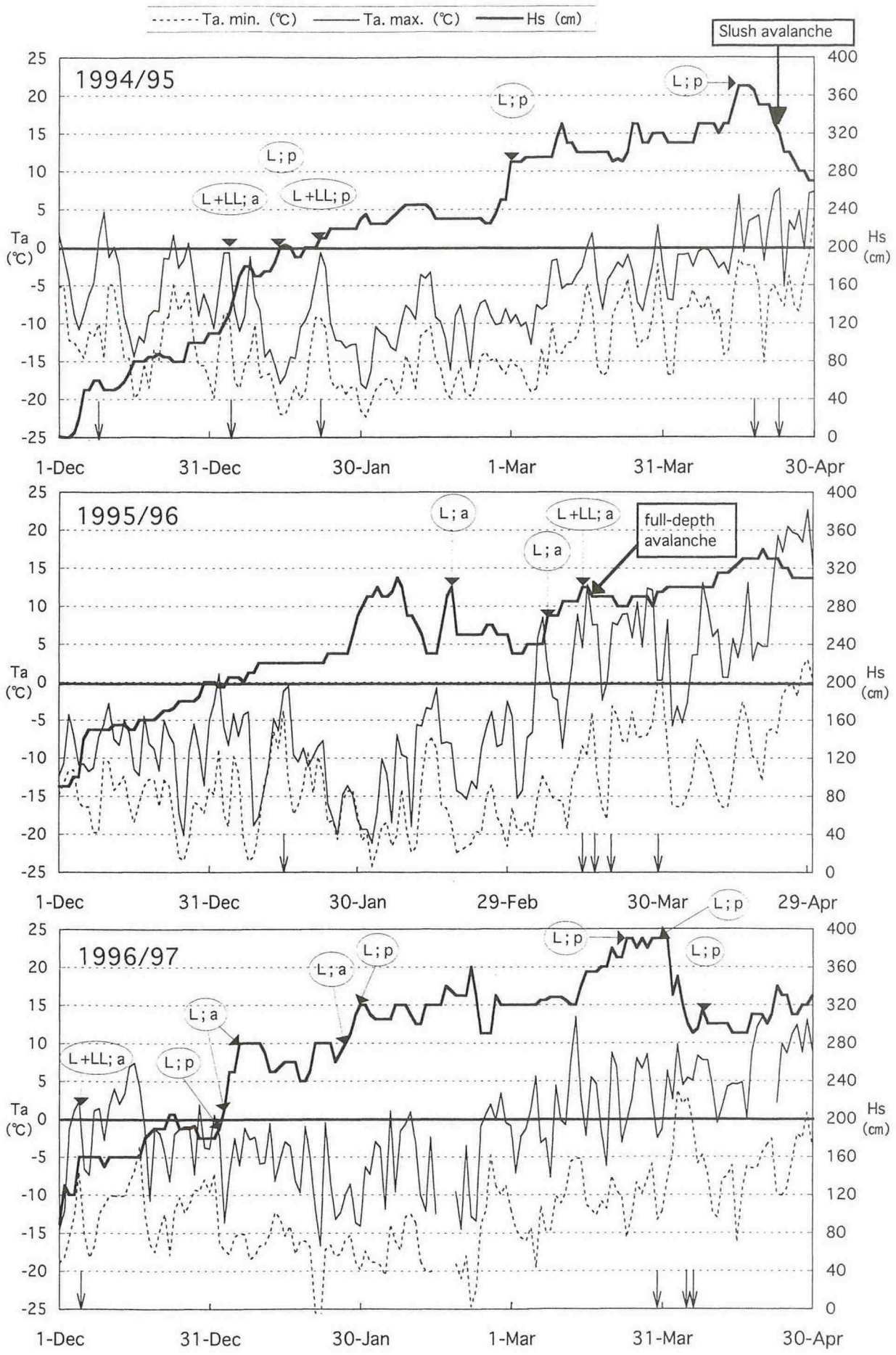


Fig. 5 The transition of meteorological data for each season.

Arrow on the date line : More than 30 mm precipitation on Miyata Hill.

METEOROLOGICAL CONDITION

To find the relation between daily meteorological data and avalanche activity, we have used the following data series of 2 weather stations: i.e. Senjojiki Bowl and Miyata Hill.
Precipitation (mm): over 24 hours (0:00 - 24:00) at Miyata Hill,
Maximum and minimum air temperature (℃): at Senjojiki Bowl,
Snow depth (cm): 9:00 a.m. at Senjojiki Bowl.
To make up for the shortcomings in the Kinoshita avalanche data, our data of snow and avalanche observation near Senjojiki Bowl have also been applied, as shown in Table 2. Fig. 5 shows the transition of meteorological data for each season. Table 3 shows the possibility of categorizing into 4 combinations, namely:

1. cold snow storm type (high-winter: the period of near-continuous ice days),
2. warmer snowy type (high-winter),
3. wet snowy type (late-winter) and
4. rain storm type.

These contribute to produce the larger natural avalanches. Fig. 6 shows the range of avalanching conditions for the first three types depending upon precipitation at Miyata Hill. Type 4 has a lower limit of precipitation (45 mm at Senjojiki Bowl and 79 mm at Miyata Hill) coupled with positive maximum air temperature.

Table 2 Data obtained at each observation point.

Observation point	Elevation (m)	Starting year	Information of avalanche	Structure of snow-pack	Snow depth	Air temperature	precipi-tation
Senjojiki Bowl	2640	1987	◎	×	◎	◎	△
Nishikoma Forest	2500	1995	○	○	○	○	×
Miyata Hill AMeDAS	1660	1973	×	×	×	◎	◎

◎: *Everyday* ○: *Monthly* ×: *No data* △: *Rain precipitation only*
∗: *Automated Meteorological Data Acquisition System of Japanese Government*

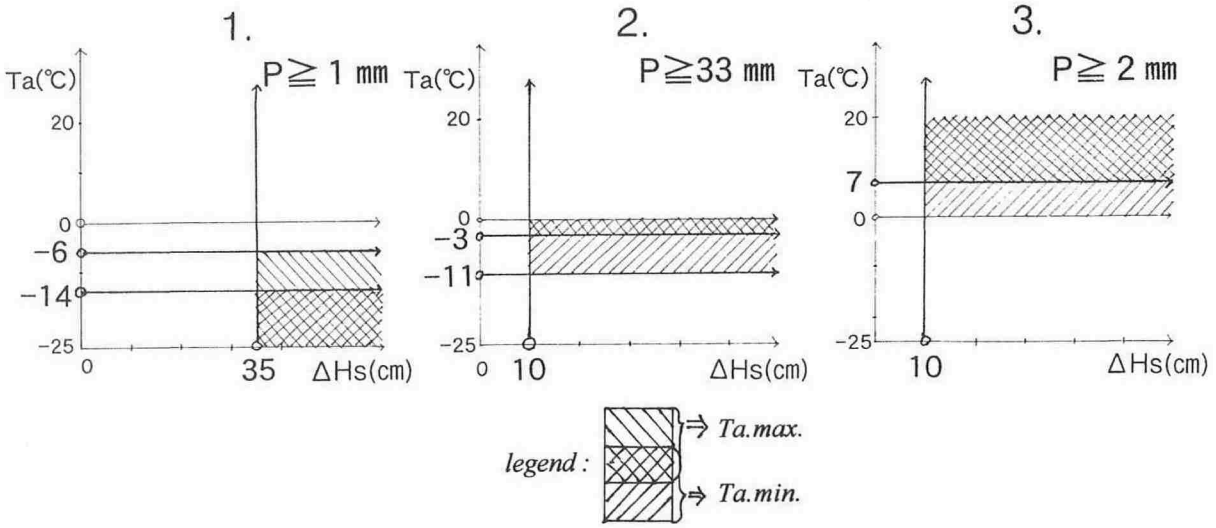


Fig. 6 The range of avalanching conditions 1., 2., 3.

Table 3 Four types of L size avalanche in and around the bowl.

Date and meteorological data.

Type	1.	2.	3.	4.
1994/95	14.Jan (35cm,-21.9℃,-17.9℃) 1.Mar (55cm,-14.8℃,-9.9℃)	4.Jan (30cm,-8.7℃,-0.7℃) 23.Jan (10cm,-10.6℃,-2.6℃)	15.Apr (20cm,-1.7℃,6.9℃)	23.Apr 【Slush avalanche】 (-6.6℃,7.7℃) (S 118mm,M85mm)
1995/96	18.Feb (60cm,-18.5℃,-8.1℃)		8.Mar (30cm,-13.7℃,1.8℃) 15.Mar (15cm,-8.4℃,4.5℃)	17.Mar 【Full-depth avalanche】 (-4.0℃,7.5℃) (S 45mm,M93mm)
1996/97	3.Jan (30cm,-17.2℃,-13.6℃) 6.Jan (70cm,-15.1℃,-6.1℃) 27.Jan (40cm,-15.9℃,-9.9℃) 30.Jan (30cm,-19.9℃,-14.1℃)		21.Mar (20cm,-7.5℃,8.7℃) 30.Mar (10cm,-13.3℃,-2.5℃) 8.Apr (25cm,-4.7℃,7.7℃)	5.Dec (40cm,-7.0℃,2.3℃) (M79mm)

Date

(Increment of snow depth, Ta.min., Ta.max.)

S : Senjojiki Bowl M : Miyata Hill

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