

2.9. Avalanches

Walter J. Ammann

Catastrophes involving large numbers of heavy avalanches lead to severe loss and damage. In Switzerland, they normally result from rapidly alternating north-westerly and southerly weather situations, with heavy precipitation and new-snow cover of well over 1 m. During the 20th century, winter snow cover neither increased nor decreased at the Alpine stations examined and no changes were observed in the activity of avalanches causing damage. It is not possible to make reliable predictions of changes in the activity of avalanches causing damage as a result of climate change.

Definition, significance and extent

In mountainous countries such as Switzerland, avalanches are a serious natural hazard. Many avalanches occur every winter. An avalanche denotes the entire displacement process of snow masses from the starting zone via the avalanche track to the deposition area. Avalanches can be classified based on purely visible, morphological, features in the starting zone, in the avalanche track and the deposition area. Also, avalanches differ significantly in magnitude.

Avalanches consisting of relatively small masses of snow, with short tracks and predominantly flowing movement occur every winter, and are known as slab avalanches. They occur throughout the winter and are evenly distributed in space and time. In Switzerland, the number of casualties averaged over several years is 23 per year (cf. Chapter 1.6.2).

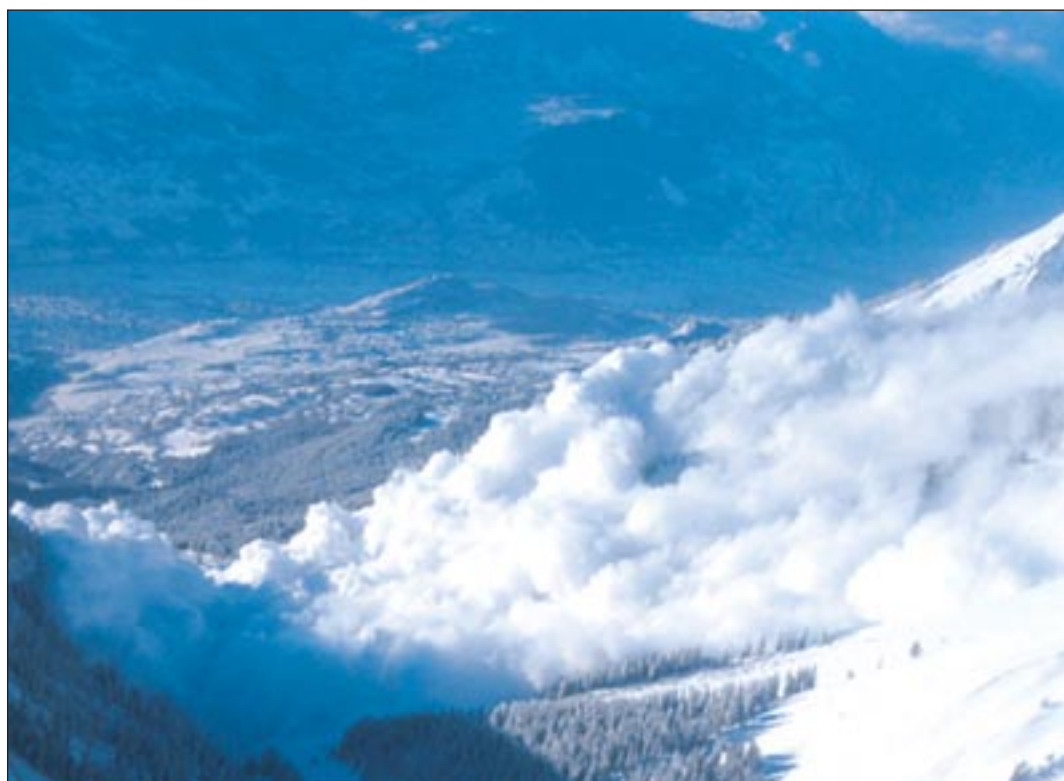
Avalanches involving large volumes of snow and having long tracks (often up to several kilometres) are referred to as catastrophic avalanches, large-scale avalanches or valley avalanches. In addition to the more frequent flowing snow avalanches, powder avalanches, or a combination of flowing snow and powder avalanches, often occur. The term flowing snow avalanche is applied to compact falling snow masses, whereas powder avalanches involve swirling motion and entrainment of the snow masses in the air.

Extreme avalanches occur relatively seldom

in any particular area. Their return period is 10 to 30 years, but for extremely large avalanches as many as 100 years and more. They are referred to as 'avalanches causing damage' when they lead to injuries, and damage built-up areas and transport routes. They have repeatedly led to large numbers of casualties and damage to material assets in the past, the last case of which was in February 1999. At that time, over 1200 avalanches causing damage claimed 17 human lives and caused losses of over 600 million CHF.¹ Extreme events of this nature are catastrophes in the true sense of the word.

Origin and conditions

Extreme events involving a large number of destructive avalanches occurring during the same period and distributed over a large area always originate under specific weather conditions. In the Swiss Alps, these are usually characterised by rapidly alternating north-westerly or southerly flow situations leading to heavy snowfall over several days and to new-snow



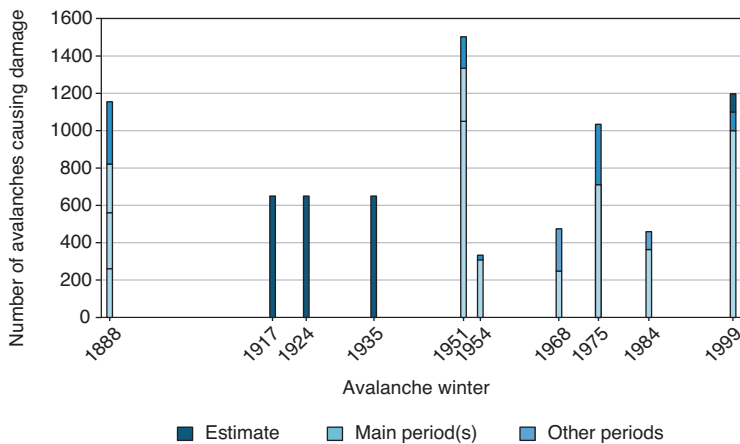


Fig. 44 The catastrophic avalanche winters in the Swiss Alps since 1887/88. The comparison is based on the number of avalanches causing damage. An avalanche causing damage includes avalanches that – for example – damage an Alpine hut, demolish a house, or block a main road. The bars shown are divided according to the main avalanche periods. In 1888, there were three distinct avalanche periods (between mid-February and the end of March), and in 1951 there were two (in January and April). The data for 1916/17, 1923/24 and 1934/35 were estimated.^{2,3}

cover of well over 1 m. Weather conditions of this kind can occur throughout the winter from December to April, whereby, however, the resulting heavy snowfall does not necessarily lead to a catastrophic avalanche situation. In the avalanche winter of 1999, the prolific snowfall in February led to an accumulation of new snow with a total depth of over 5 m.¹ Extreme precipitation periods of this kind are often accompanied by storm winds, resulting in extensive drifting of the new snow, and, particularly on steep slopes in the vicinity of ridges, to further accumulations of snow. Under these conditions, large-scale avalanches can occur with a starting magnitude (i.e. thickness of the departing snow layer) of several meters, a starting width of over 1 km, and a volume of up to one million m³.

As a rule, the starting zone of large-scale avalanches lies considerably above the tree line. In the avalanche winter of 1999, the starting zones lay at an average of 2300 m altitude. Large-scale avalanches descend at very high speeds into the valley. Flowing snow avalanches attain a speed of over 100 km/h and powder avalanches up to 300 km/h. The destructive power of large-scale avalanches is very large, and pressures of up to 1000 kN/m² can occur. It would be inconceivable to protect building structures from such high pressures. During their descent, the snow masses lose energy through friction.

Since, however, the friction between the gliding snow masses and the ground is only small, flowing snow avalanches do not come to rest until the terrain becomes flatter, i.e. at slope angles below 12°. Therefore both the area affected and the destructive force of a large-scale avalanche are very large.

Under springtime conditions, or when rain saturates the snow layer, the intensity of the avalanche may be higher. Wet-slab avalanches, however, have higher frictional resistance. They are therefore significantly shorter than dry avalanches in midwinter, even with comparable volumes of descending snow.

Historical avalanche catastrophes and identifiable trends

Avalanche winters in the past

Extreme events comparable to the avalanche winter of 1999 occurred in the winter of 1950/51, claiming 95 lives⁴, and in the winter of 1887/88 (Fig. 44). Furthermore, similar extreme events are known to have occurred over the entire Alpine region in previous centuries.⁵

In the period after 1500, large-scale avalanche events are increasingly documented. Since 1888, all larger events causing damage have been recorded. Prior to that, the data are sporadic. Since 1945, all reported avalanches causing damage have been recorded individually in a special archive at the Swiss Federal Institute for Snow and Avalanche Research (SLF). This database enables a detailed impression to be gained of the temporal and spatial distribution of avalanches causing damage in the region of the Swiss Alps. In combination with meteorological data, the probability of avalanches causing damage occurring under particular weather conditions can be estimated. For this purpose, historical data extending as far as possible into the past were prepared for Andermatt, Bever and Davos in the context of the National Research Programme, NFP31.⁵ All sites lie at

approximately the same altitude (around 1500 m a.s.l.) but in climatically different regions of the Swiss Alps. Data on the thickness of snow cover are available at daily intervals since 1896 for Davos, 1910 for Bever and 1947 for Andermatt.

Based on this data, trends in snow cover during the 20th century were studied. For the Davos site, a parameter describing the activity of potential avalanches causing damage was determined based solely on meteorological data. The following conclusions may be drawn from the evaluation (cf. Fig. 45):

- (a) Snow cover varies considerably from year to year. However, no trend could be identified over time, since today, the average winter temperature still lies well below 0°C. In recent years, the thickness of snow cover at the stations investigated was not unusual. A slow downward trend in average snow cover was identified during the 1990s. However, years with a snow deficit had also occurred at frequent intervals in the 1920s.
- (b) In the case of Davos, the activity of avalanches causing damage has neither increased nor decreased (cf. Fig. 45).
- (c) Events causing damage are restricted to individual regions. In the course of the last 600 years, the case of all Alpine regions in Switzerland being affected simultaneously by avalanche catastrophes has never occurred. There is no identifiable trend indicating increased or reduced avalanche activity.

Safety measures and losses

Following the avalanche winter of 1887/88, the first structural measures for the protection of residential areas from avalanches were taken. Initially, stone-blocks were used to terrace the slopes, and later, retaining structures – mostly in steel – were built to stabilise the snow masses in the starting zone. These efforts were strongly intensified following the avalanche winter of 1950/51. To date, the Swiss Confederation has invested some 1.5 billion francs in avalanche defence structures.

The extensive losses occurring in the avalanche winter of 1999 should not be taken as grounds to question the effectiveness of the safety measures taken in earlier decades. On the contrary, the preventive activities extending

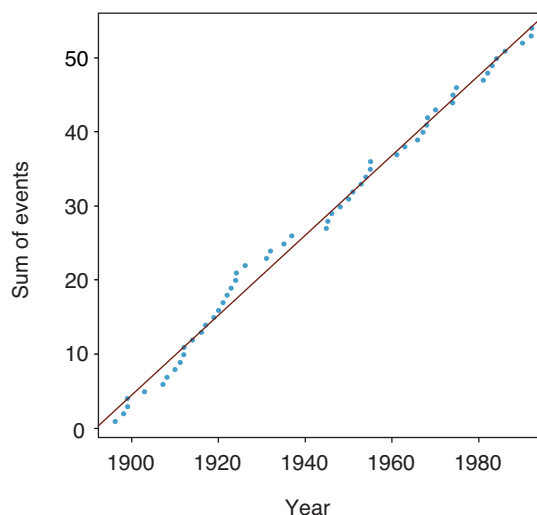


Fig. 45 Date and sum of events with snow cover and 3-day new-snow cover, each greater than 75 cm. The straight line shows the average trend between 1896 and 1993 for Davos. Time periods with potentially higher avalanche activity are steeper than those with low avalanche activity.⁵

over many years with the collaboration of the communes, cantons and the Confederation have stood the test! Since 1950/51, the susceptibility of humans and material assets to damage has increased enormously, leading to an increase in the risks.¹ Despite this, about six times less lives were lost in 1999 than in 1950/51. The material losses increased only slightly above the insured value of buildings and infrastructure. With the aid of organisational, technical and land-use planning measures, in combination with the large-scale protective function of the mountain forests, it was possible to maintain the damage in Switzerland within tolerable limits.

Influence of climate change

Extreme situations resulting in avalanches occur as a result of exceptional weather constellations leading to massive snowfall above about 1200 m altitude over several days.

It is expected that climate change will lead in future to an increased average air temperature and to an increase in precipitation and in the frequency of extreme weather situations in winter. Very few studies on this exist, and those that do only calculate the influence of increased temperature on snow cover and avalanche activity.⁶ The influence of other changes – alone and in combination – on snow cover and avalanche activity has not yet been studied. It is therefore only pos-

sible to provide qualitative estimates⁷ as follows:

- (a) The snowline will rise several hundred metres as a result of warming. Taken in isolation, warming will generally result in thinner snow cover of shorter duration.⁶
- (b) In contrast, the increase in precipitation above the tree line in winter, i.e. in potential avalanche starting zones, will lead to thicker snow cover. If the increase in precipitation occurs mainly during exceptional weather situations, and is not therefore spread over the whole winter, the risk of extreme avalanche situations will increase.
- (c) At present, approximately every third exceptional weather constellation in winter leads to an extreme avalanche situation.¹ Thus with the increasing frequency of exceptional weather conditions during the winter months, the probability of an extreme avalanche situation arising in winter will also rise.
- (d) At lower altitudes, more frequent rainfall on the snowpack may lead to an increase in wet-slab avalanches. However, as this situation is already common in spring, the risk would hardly be expected to rise.

- (e) In general, gliding of the snow layer over the vegetation will attain greater significance as a result of climate change, and the resulting shear forces could cause increasing damage to vegetation and to the landscape.

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- 1 SLF, Der Lawinenwinter 1999 – Ereignisanalyse. Eidg. Institut für Schnee- und Lawinenforschung, Davos, 588 S., 2000.
 - 2 Source: SLF database on avalanches causing damage.
 - 3 Calonder G. P., Ursachen, Wahrscheinlichkeit und Intensität von Lawinenkatastrophen in den Schweizer Alpen, Diplomarbeit Geographisches Institut der Universität Zürich, 1986.
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 - 5 Schneebeli M., M. Laternser, P. Föhn und W. Ammann, Wechselwirkungen zwischen Klima, Lawinen und technischen Massnahmen, Schlussbericht NFP31, vdf, Zürich, 132 S., 1998.
 - 6 Föhn P. M. B., Climatic change, snow-cover and avalanches, CATENA, Supplement 22, 11–21, 1992.
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