AVALANCHE ACCIDENTS IN ITALY: INVESTIGATIONS OF AVALANCHE RELEASE

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ABSTRACT: On the Italian Alps, avalanche fatalities are about 20 each winter season. The categories of ski mountaineers and free riders are the most affected, as is historically known. Most avalanche releases occur along slopes with 38.5° of mean estimated slope angle with an increasing trend in the last ten years (39.5°). The long-term average release elevation is 2450 m, which has increased to 2510 m in the previous ten years. The highest elevation is for the mountaineers, almost at 2700 m and the lowest among snowshoe hikers (2050 m) and snowmobilers (2250 m). Most avalanche accidents (52%) occur along slopes in the NW-N-NE aspects. However, the SE sector is also a critical aspect that, together with the E, accounts for about one-quarter of accidents.

For 2017- 2023, 110 avalanche accidents (with and without fatalities) were investigated to define the avalanche bed surface. For 91 accidents, it was possible to determine whether the breaking surface was a thin, weak layer or a layer-to-layer contact surface. In the former case, 44% of the bed surfaces were a persistent weak layer formed by embedded surface hoar (SH), faceted crystals (FC), or a thin layer of melt forms (MF). Added to these was a thin layer of decomposed and fragmented particles (DF), most often attributable to a recent snowfall.

In the remaining 59% sample, breakage was assigned to the point of contact between layer and layer, where in most cases, the base layer consisted of faceted crystals (FC) or with depth hoar (DH), often mixed, a 16% from melt forms (MF), a 7% from rounded grains (RG) and a remaining 8% from decomposed and fragmented particles (DF) but with a thickness that could not be ascribed to the class of thin layers.

KEYWORDS: Avalanche Accidents, Snow Structure, Avalanche Release

1. INTRODUCTION

In 1984, the Italian Alpine Regions and Provinces, from Liguria to Friuli-Venezia Giulia, formed the "Interregional Association for the Coordination and Documentation of Snow and Avalanche Problems" called AINEVA. The Association works, among other things, to collect information on avalanche accidents for statistical purposes and to understand the phenomenon (avalanche characteristics and behaviour of those involved).

AINEVA's accident database has more than 40 years of certified data, which have been fed into the international EAWS database (www.avalanches.org). Today, the phenomenon and movement of recreationists is no longer linked to a valley or simple spring skiing, as the ski mountaineering publications of the 1970s described, but is a global movement in search of 'snow' in all seasons of the year.

In addition to simple statistics on the categories involved and the morphology of the release area, AINEVA has sought to deepen its knowledge of the phenomenon to update its didactic and support material.

2. THE AVALANCHE ACCIDENT

Avalanche accidents are classified as all those known releases where a skier/hiker is involved, not necessarily buried or injured. The definition of "known accident" encompasses two concepts: being aware of the phenomenon's occurrence and having collected the essential information to be entered into the AINEVA database. Therefore, as a general rule, all avalanche accidents in the database have specific documentation at the regional/provincial AINEVA avalanche office.

The collected information has varied over the decades. However, it usually concerns the number of people present, the people caught in the avalanche, their state when the avalanche stopped (buried, half-buried, on the surface), whether they were injured, unharmed or dead, the method of finding the people caught (self-rescued, avalanche beacon, probes, K9 units, etc.), the sporting/recreational activity practiced or the anthropized area (home, street), the profession of the people caught concerning alpine activities (mountain professionals, ski lift operators, ski-lift operators, road maintenance operators, etc.) and information on the avalanche itself, such as elevation, aspect, slope, width and release thickness. In the most accessible cases, the avalanche warning service, in the first days after the event, carried out a stratigraphic survey to investigate the avalanche surface, the type of avalanche (slabs, loose snow) and other safety information (whether the avalanche victims had ABS equipment, etc.).

This documentation made it possible to understand the phenomenon of recreational activities in the mountains, to understand new trends (off-piste skiing with snowboards, snowshoe hikers, etc.) in advance, and to make changes/corrections to the information documents, e.g. by integrating the avalanche danger scale with the activities of the snowshoe hiker defined as weak overload.

A recent study carried out by the SFL in Davos using users' GPS routes combined with avalanche accident data established that the risk (not the danger) of avalanches quadruples from one danger level to the next: if, for example, one is in an area with a '3-considerable' danger level, the risk is 17 times higher than when the danger level is '1-low' in the same area (Winkler et al. 2021).

3. THE MAIN DATA

The database consists of 1894 known accidents from the first accident on 12.01.1984 Pale di San Martino [TN] to the accident on 07.06.2023 Ortles [BZ], which caused 824 fatalities.

Figure 1 shows the number of known accidents, fatalities and the number of victims over the four decades.

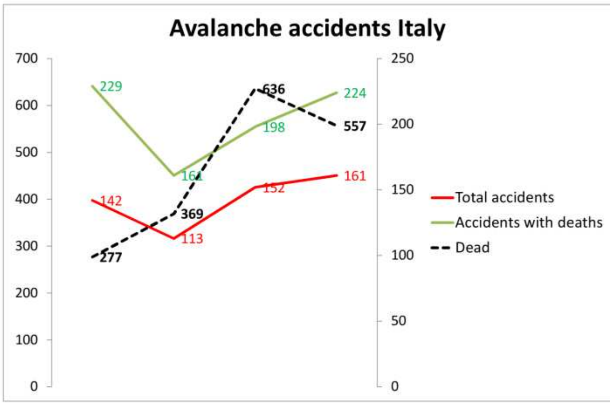

Figure 1: Breakdown of the number of accidents and fatalities for the four decades (1984 - 1993, 1994 - 2003, 2004 - 2013, 2014 - 2023).

Accidents over the decades vary in number due to a greater increase in the recent 20-year period as a result of greater attention to documenting events. Interestingly, despite a decline in accidents in the recent decade, the number of fatalities is still rising.

Statistically speaking, for every 100 accidents known over the last 10 years, 29% are fatal (31% on average over 40 years), with a fatality rate of 0.4 or 1 death for every 2.5 accidents. This value, of the same order of magnitude as for the previous two decades, is very high compared with other types of accident. For car accidents it is 0.02.

The Figure 2 shows the areas with the most accidents in the AINEVA database according to the SOUISA Alpine subdivision.

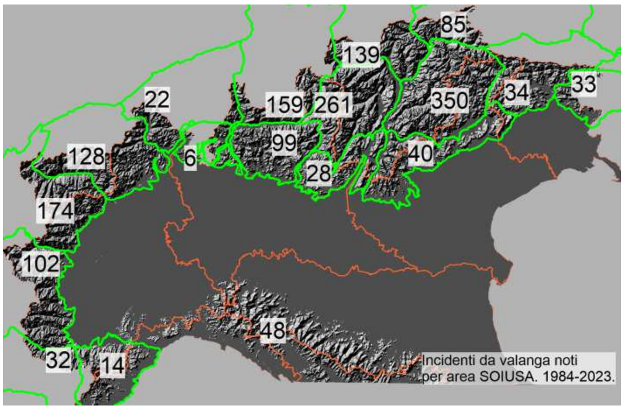

Figure 2 Number of accidents per Alpine area (SOUISA subdivision).

4. AVALANCHE VICTIMS CATEGORIES

In terms of the categories caught in avalanche accidents, ski mountaineers account for about 50 per cent, more in downhill than uphill.

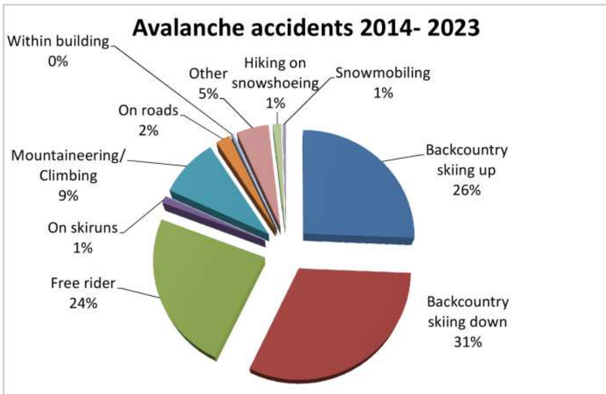

Figure 3: Avalanche accidents by categories in the recent decade 2014 - 2023.

In the last 10 years (Figure 3) there has been a peak of accidents during downhill skiing with 31% of the total, compared to an average of around 26%. Also on the downhill, free riders account for about ¼ of all those caught, followed by mountaineers (9%). The category of mountaineers peaked in the 1990s when snow was scarce and winter climbs, especially along waterfalls, had become more frequent. Between 2004 and 2013, 5% of accidents involved snowshoe hikers: this is a period of strong expansion of this recreational activity on the snow.

The free rider category includes both skiers and snowboarders. The trend over the last 20 years is a positive trend (increase) in accidents in downhill skiing and a negative trend (decrease) in free riders. In the latter category, the lack of cases in the non-ski seasons due to the pandemic plays a role.

Accidents in anthropized and actively managed areas (ski slopes, built-up areas, roads) account for 5-7% of the total. The Rigopiano tragedy of 18th Jan 2017, with as many as 29 deaths, is worth mentioning.

In skiable areas, 30% of accidents were observed considering free riders (ascending with the ski lift and descending) with 474 accidents, skiers on open or presumed open ski slopes with 39 accidents and another 40 involving ski lift operators and ski patrollers in various situations.

In the last 10 years, 63 out of 557 accidents (11% of cases) involved foreigners, very often mountain guides.

5. ACCIDENTS AND MOUNTAIN PROFESSIONALS

Accidents also occur involving mountain professionals, both at work (accidents at work) and in recreation activities.

In 40 years, they account for 13 per cent of the total (same percentage in the last 10 years), with mountain guides predominantly involved, followed by ski instructors and ski lift operators (piste groomers predominantly) (Figure 4).

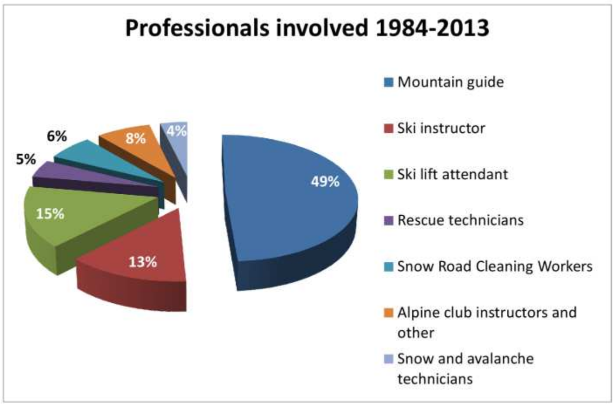

Figure 4: Avalanche accidents among mountain professionals. The total represents about 13% of the database.

It should be noted that there is no shortage of accidents among snow observers, mountain rescue workers often during a rescue phase, instructors of the Alpine Club (CAI) and other associations members.

Therefore, the avalanche accident can also be considered, for certain categories, as a work accident and therefore appropriate training must be carried out (which already takes place in part) using the appropriate equipment (also defined as Personal Protective Equipment – DPI in Italy).

6. AVALANCHE RELEASE AREAS

Most avalanche releases occur on slopes that have an estimated average angle of 38.5°, with the trend over the last 10 years increasing (39.5°). In fact, comparing the data from the decade 2004-2013 with 2014-2023, the increase in the average value is of almost 2° of slope inclination for ski mountaineers in descent and 3° (average value of 44° of inclination) for mountaineers is immediately evident, while the increase by free riders is less important +0.8° equal to a mean value of 38.5°. The median values also give the same trends. Analysing the data for the last 20 years, the linear time trend line shows a +0.15° with an R^2 of 0.47 (Figure 5).

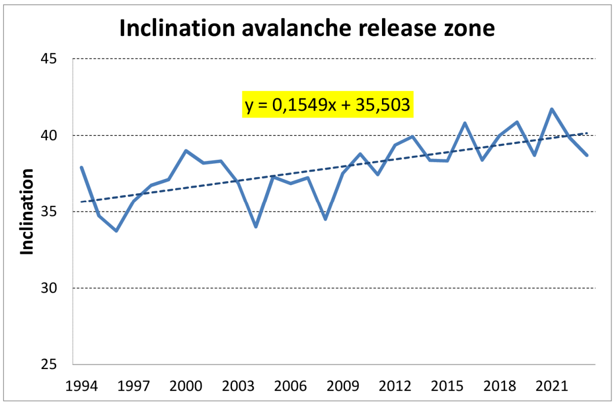

Figure 5: Average slope inclination value in the avalanche release area. Period 2014 - 2023.

The long-term mean elevation is 2450 m, which has increased to 2510 m in the last 10 years. For the elevation, the trend line is also positive. The highest elevation is for the group of mountaineers at almost 2700 m and the lowest among snowshoe hikers (2050 m) and snowmobilers (2250 m). The average altitude along roads is about 1900 m (Figure 6).

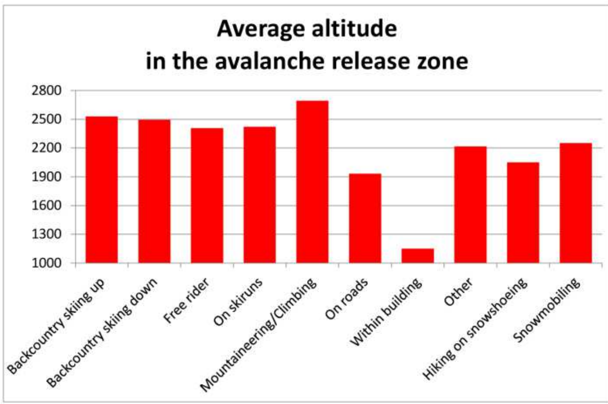

Figure 6: Average slope altitude in the avalanche release zone for the different categories. Period 2014 - 2023.

Most avalanche accidents (52%) occur along slopes in the NW-N-NE aspects, but the SE sector is also an important one, accounting together with the E sector for about a quarter of accidents. The large S-SW-SE sector is relatively less affected by avalanche accidents.

Accidents for ski mountaineers occur mainly in the NW to SE through N aspects (76-80% of cases) (Figure 7), while for ski mountaineers most accidents occur in the SE-SW-W sun-exposed aspects (77%) and for snowshoe trekkers SE-SW (54%).

Thus we have accidents increasingly at higher altitudes and on steeper slopes.

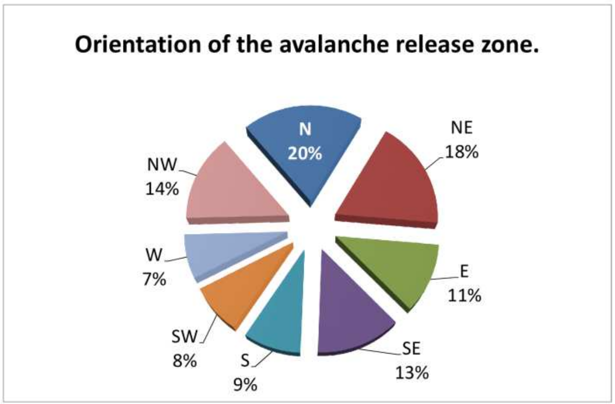

Figure 7: Aspects distributions of avalanche release zones. Period 2014 - 2023.

7. ACCIDENTS AND AVALANCHE PROBLEMS

The 'Avalanche Problems' describe the condition that most commonly determines the avalanche danger during the validity period of the avalanche bulletin and are grouped into five types: New snow, Wind slab, Persistent weak layers, Wet snow and Gliding snow.

These 'Avalanche Problems' are not to be confused with the types of bed surfaces described in the following chapter, although they are strongly related. Often, the avalanche forecaster describes in the bulletin the Avalanche Problems that are visually easiest for the user to perceive (e.g. Wind slab) despite the presence of persistent weak layers beneath.

From 2017 to 2023 (7 winter seasons) there are 292 avalanche accidents for which the "Avalanche Problems' indicated in the avalanche bulletin in the area where the event occurred.

In 64% of the cases the situation indicated is 'Wind Slab', followed by 'New Snow' and 'Wet snow' and then 'Persistent weak layers' (Figure 8).

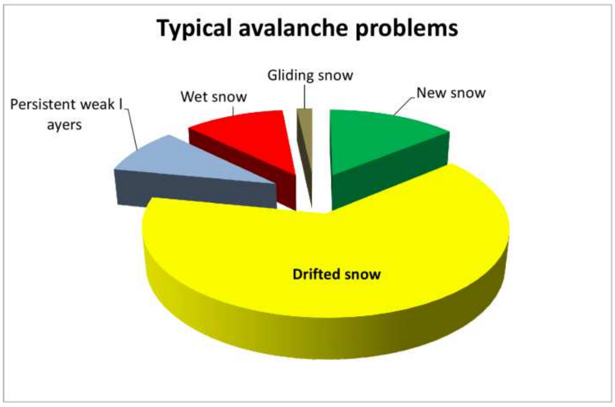

Figure 8: Typical situation indicated in the avalanche bulletin in the accident area. Data set of 292 accidents in the period 2017 - 2023.

Cross-checking the avalanche danger level and "Avalanche Problems, extracted from the avalanche bulletin at the accident site (Figure 9), 'Wind slab' problem dominate the cases with danger level 3-considerable, 'New snow' problems are characteristic of the higher danger levels and 'Wet snow' situations are characteristic of the low ones. From the data-set analysis, there is no evidence of 'Persistent weak layers', although it is frequent as a weak layer type.

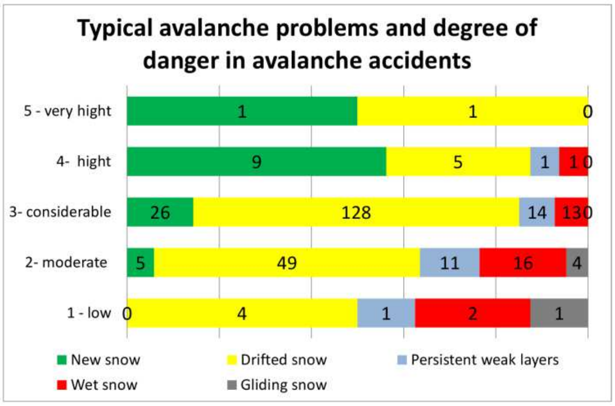

Figure 9: Cross-reference between the danger level and the Avalanche problems indicated in the avalanche bulletin for the area related to the accident.

8. ACCIDENTS AND BED SURFACES

The investigation of the snowpack bed surface in the release zone that allowed the avalanche, whether spontaneous or triggered, has always been a reason for deepening and verifying the avalanche forecaster's intuition in identifying critical scenarios.

De Quervain and Maister (1987) grouped the snowpack bed surfaces (spontaneous and triggered avalanches on the basis of 50 winter seasons in the Davos area) into eight combinations and found that in 17% of the cases, the bed surface was due to the presence of surface hoar (SH) buried in the snowpack, and that in most cases the base layer consisted of old snow (FC and DH).

Birkeland (1997) also found in the Bridger Mountains, Montana, that buried surface hoar (SH) was the most frequent avalanche bed surface in the area (31%) and that 65% of the bed surface was represented by crystals due to kinetic growth.

On the basis of this work, and in order to understand the analogies with the reality of the Italian Alps, an initial research work was conducted in 2011 on about one hundred avalanche accidents that occurred in the period 2000 - 2010 in the Dolomites. In this work, published in Italian, in the Journal Neve e Valanghe no. 72 (Valt, 2011), we confirmed the evidence of bed surfaces due to surface hoar (SH) and kinetic formation crystals (FC and DH), but also a large component of avalanche accidents due to the presence of wet snow (MF), melt-freeze crusts (MFcr) buried in the snowpack and recent (soft) wind slabs (DF).

We have updated this analysis by studying 110 out of 329 avalanche accidents in the period 2017-2023 (Figure 10). For 87 accidents, it was possible to define whether the bed surface was a thin weak layer or a contact surface between layer and layer. In the former case, 40 percent of the bed surfaces were a persistent weak layer formed by buried surface hoar (SH), faceted crystals (FC) or a thin layer of frozen snow (MF). In addition to these, there is a thin layer of decomposed and fragmented particles (DF), which was most often attributable to a recent snowfall.

In the remaining sample of 59%, the breakage was assigned to the point of contact between layer and layer, where in the majority of cases, the basal layer is formed by faceted crystals (FC) or with depth hoar (DH), often mixed, 16% by melt forms (MF), 7% by rounded grains (RG) and the remaining 8% by decomposed and fragmented particles (DF) but with a thickness that cannot be ascribed to the class of thin layers.

From this sample of data from accidents observed throughout the Italian Alps, it can be seen that in 78% of the cases the sliding layer is formed by an "old" wind slab or "recent" (soft) wind slab (DF mixed with RG). This characteristic agrees with the greater frequency of the 'Wind slab' Avalanche problem reported in the bulletins, even though in 34% of the cases the bed surface is a weak persistent layer, overlaid by DF and RG grain types.

Analyzing the types of crystals brought into play in the bed surface, the most prevailing forms are from melting forms (MF) with 38% of cases, followed by kinetic growth forms (FH and DH - 33%), decomposed and fragmented particles (DF) and finally surface hoar crystals (SH - 13%).

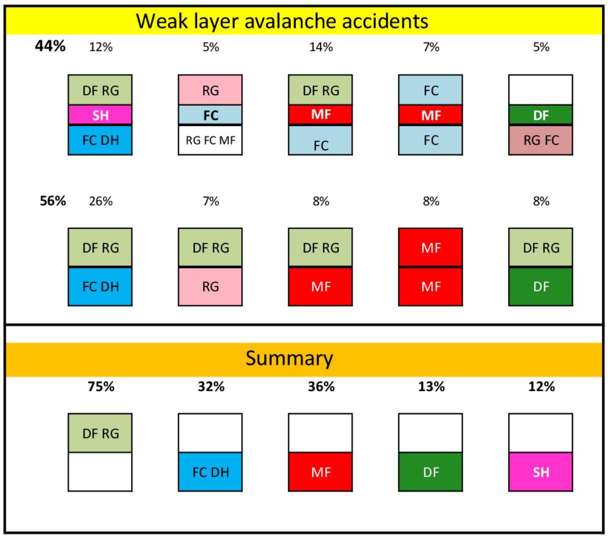

Figure 10: Avalanche accident bed surfaces. Data base of 87 out of 329 avalanche accidents in the period 2017 - 2023 for the entire Alpine region.

9. CONCLUSIONS

About 100 people die in avalanches per winter season in the Alps and 19-20 in the Italian Alps. The number is not high compared with other cases (e.g. mushroom hunters and hikers), but the avalanche accident has a high risk index (0.42).

The documentation of avalanche accidents and the availability of analyses on unitary databases makes it possible to study snow dynamics and users behavior in order to target training, information and accident prevention.

Ski mountaineers are the most affected category followed by free riders. It can be observed that in the last decade accidents occur more frequently and on steeper terrain.

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